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by

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by

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PREFATORY NOTE.

In proportion as the critical breeding work with herbage plants progresses the need of a more detailed knowledge of the behaviour of different species and strains of grasses and clovers under different conditions is felt. In consequence, critical agronomic work with grasses and clovers has as far as possible to keep pace with the breeding work. As explained in a prefatory note to a previous bulletin, the preliminary garden trials showed the necessity of following up the teaching and implications of these with investigations conducted in greater sympathy with field conditions. Field trials can, of course, very properly be conducted by resort to very small plots—the essence of a field trial is to introduce ordinary farm conditions. This in the case of herbage plants implies the intervention of the grazing animal. In order to conduct small scale field trials to the best advantage it soon became apparent that it was desirable to understand not only the reaction of the sward to the grazing animal, but equally to endeavour to understand the reaction of the grazing animal to the sward. The experiments reported upon in this bulletin have therefore been designed primarily with a view to the better understanding of the interaction of animal and pasture.

Small scale trials are not easy to conduct, and in a sense in so far as any particular station is concerned they are a matter of evolution. It is only possible to conduct such trials with supreme care and accuracy if the endeavours of the research staff are supported by the whole hearted co-operation of both the technical staff and the farm and garden staff. The necessary close co-operation is only possible if the utmost patience is exercised in the training of what may be described as the non-commissioned workers—above all their interest must be aroused in the work in hand.

The trials under review, and indeed a very great proportion of the investigations in progress at the Station, are dependent to a marked degree on the accurate and painstaking endeavours of both technical assistants and farm and garden staff. It is a pleasure, therefore, to place on record a high sense of appreciation of the manner in which the work which falls to the non-commissioned staff is at all times performed. In this connection thanks are equally due to the research staff and to Mr. Watkins, the Superintendent of the Farm and Gardens, for the manner in which they have trained the workers for whom they are responsible to perform their various technical duties.

In conclusion it is my desire to express thanks to Miss Rhoda Jones, B.A., for assistance with reference to literature and for seeing this bulletin through the press.

R. G. STAPLEDON.

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INTRODUCTION.

The provision of grazing or of green fodder for sheep during the winter, and especially in the early spring when the ewes are feeding their lambs and before the pastures begin active growth, is a serious problem to farmers in districts where folding is not practised.

This is a question which has been under investigation at the Station since 1919—results of previous trials having been reported upon by Stapledon and Williams (6)*, and by Williams (8).

These results, together with trials conducted by Professor White at Bangor, have shown that the difficulty can be largely overcome by sowing Italian rye-grass in the corn and utilising the herbage developed on the stubble for autumn, winter and spring grazing.

It is generally admitted by flockmasters that perhaps the most important aspect of the problem is to ensure a sufficiency of nutritious herbage from the middle of March until the middle of April.

It was therefore decided to set up an experiment designed primarily to ascertain the effects of different methods of grazing during the autumn and winter on the amount, nutritive value and palatability of the herbage offering at about the end of March ; and also with a view to noting the progressive changes in respect of these three important properties of the herbage during the autumn and winter.

THE FIELD : PREVIOUS TREATMENT AND NATURE OF THE SOIL.

The experiment was carried out in the Spring Field of the Plant Breeding Station, the soil being a light loam formed from the Aberystwyth grits but slightly deeper than the general run of these soils. Its mechanical and chemical composition was as follows :—

	<i>Soil.</i>	<i>Subsoil.</i>
Fine gravel.	29.7	22.5
Coarse sand.	13.5	12.3
Fine sand.	11.2	13.4
Silt.	9.8	11.9
Fine silt.	16.0	21.7
Clay.	4.5	6.6
Loss on ignition.	12.10	7.96
Moisture.	4.72	3.90
Nitrogen.	0.35	

* Reference by number is to Literature Cited p. 41.

After 48 hours digestion with HCl.

Potash (K_2O)	0.57
Phosphoric acid (P_2O_5).	0.19
Calcium oxide (CaO).	0.16

Soluble in 1 per cent. citric acid.

Potash (K_2O).	0.030
Phosphoric acid (P_2O_5).	0.016

The field from 1909-1922 was under grass and during this period received no manurial treatment, but in 1923 a dressing of basic slag at the rate of 10 cwt. per acre was applied to it. In July, 1924, the field was ploughed and in the following month sown with mustard. In February of the following year it was again ploughed, and though the tilth was not all that could be desired it was sown with oats on April 2nd, 1925.

The following day the experimental plots were marked out and the necessary seed mixtures sown.

THE CONDUCT OF THE EXPERIMENT.

The experiment consisted of four main plots, A, B, C and D, divided into duplicate sub-plots "a" and "b" respectively. The "a" series of sub-plots were each one-eighth of an acre in area and the "b" series one-sixth of an acre. The plots were arranged in a row along the bottom end of the field, the "lay-out" of the sub-plots being as follows:—

a/A, a/C, a/B, a/D, b/D, b/B, b/C, b/A.

On the "a" series of sub-plots the following seed mixture was sown:—

8 lb. Italian rye-grass.
4 „ Rape.
1½ „ Hardy green turnips.

On the "b" series of sub-plots the mixture was:—

10 lb. Italian rye-grass.
10 „ Tall fescue (indigenous).

Apart from the difference in seed mixture, the duplicate sub-plots were treated in precisely the same manner. It should, however, be noted that after the first two cuttings the crucifers and tall fescue made little contribution to the yield, the rate of establishment of the tall fescue being as usual particularly low.*

After harvesting the corn on August 20th, the eight sub-plots were hurdled off, and the management of the plots up to March 30th (hereafter referred to as the crucial date) was as follows:—

Main plot A, (sub-plots a/A and b/A).

The plot was sampled on September 21st, then grazed hard for a few days by sheep and allowed to rest until March 29th.

* The establishment of grasses and clovers under different conditions has been under investigation at the Station since 1921, and a report dealing with this is now in preparation.

Main plot B, (sub-plots a/B and b/B).

Sampled on September 21st and every month subsequently until March 29th. After each sampling the plot was grazed by sheep.

Main plot C, (sub-plots a/C and b/C).

Allowed to rest from the time of harvesting the corn until March 29th.

Main plot D, (sub-plots a/D and b/D).

Sampled on October 27th and December 30th, grazed after each sampling and allowed to rest until March 29th.

At each grazing prior to the crucial date the aim was to graze the plots absolutely bare. A careful record of the number of "sheep days" necessary to do this was kept. "Sheep day" data thus obtained on small plots does not of course of itself afford very strong evidence as to carrying capacity, but it will be shown that the figures thus obtained are in general agreement with the presumptions which the yield, botanical and chemical data would have invited.

After all the plots had been sampled on March 29th, the hurdles separating them were removed and a number of sheep were allowed free access to all the plots, with the object of ascertaining whether preference would be shown for one plot over another. The plots were grazed almost continuously for nine days and any selective grazing was carefully noted. On April 13th the plots were again sampled so as to obtain an indication of the nature of the herbage remaining uneaten.

By allowing sheep to graze the plots, a true representation of what actually takes place under ordinary farm conditions was obtained, which would not have been possible had the whole plot on each occasion been cut with a mower. Thus the sheep determined the closeness of grazing, and consequently the extent to which the plants "picked up" and re-started growth after each treatment was in no wise affected on the body of any particular plot by artificial methods of de-pasturage.

Sampling of the plots.—Five separate square yards were cut from the duplicate sub-plots, the produce from each sub-plot being kept apart. Both samples were then divided into two parts, one part—after removing the stubble—being spread out and air-dried,* the other examined botanically, the approximate amount of Italian rye-grass, weeds and burn being estimated. The Italian rye-grass was further separated into stem and leaf, the ratio of these being determined. The bulk sample and separations were then dried in an oven prior to chemical examination. The yields throughout are expressed as dry matter per acre or per plot.

I. YIELD UNDER THE VARIOUS SYSTEMS OF GRAZING.

Full particulars as to yield are set out in Tables I, II and III. It will be noted from Table II that the crucifers contributed to the dry weight to a certain extent in the first cut, but to an almost negligible extent subsequently, and that they had to all intents and purposes disappeared by December. For the purpose of discussion, therefore, the average figures for the sub-plots are in all

* This part is referred to in the paper as "bulk sample."

cases taken. It will be convenient to deal with the data under three headings : aggregate yield, autumn and winter yield, and yield at the crucial spring date.

(1) *Aggregate yield.*—The figures in Table I are of interest since they show that the total yield obtainable during the period September 21st to March 30th has been progressively greater under a system of many cuts than under a system of few cuts—the smallest aggregate amount of dry matter for the whole period having been obtained from the plots cut only in September and March.

TABLE I. *Aggregate yield from the several plots and number of cuttings (corresponding to grazings) contributing to the total.*

No. of cuts.	Series.	Month of Cuts.	Yield in lb. per acre of total dry matter.
One	C.	March only.	1012
Two.	A.	September and March.	2200
Three.	D.	Oct., Dec. and March.	2355
Seven.	B.	Monthly Sept. to March.	3521

The sub-plots cut only in March are of course not strictly comparable, since most of the growth developed prior to September 21st or October 27th (when a cut was made on the other plots) would have died back during the winter and have made but a negligible contribution to the yield of the only cut—that made on March 30th.

The above result is, on the face of it, in entire disagreement with the evidence accumulated at the Station over a number of years. Stapledon (4) has shown that in the case of a large number of the ordinary perennial grasses it almost invariably happens that the aggregate produce of a number of pasture cuts made during the ordinary growing season is less than the sum of a hay and aftermath cut, while Williams (7) has demonstrated precisely the same phenomenon for red clover.

It has, however, been further pointed out by Stapledon (4) that in the case of grasses like cocksfoot and red clover under favourable conditions for growth, and during the season of repeated cutting, the earlier and quick growing strains of a species (for example, Danish cocksfoot in contra-distinction to late indigenous, and broad red clover in contra-distinction to an extra late red clover like Montgomery) give aggregate pasture yields more closely approximating to hay *cum* aftermath yields than the later and more slow growing strains.*

Italian rye-grass is very essentially a biennial in its mode of growth and general behaviour. It has been repeatedly demonstrated at the Station that it

* Tincker at the Station in connection with his work on the effect of duration of daylight on the flowering and fruiting of plants has collected data (unpublished) from clippings on single plants of cocksfoot and other grasses grown in pots which are in entire agreement with the findings of Stapledon noted above. These data, moreover, also show that many cuts from the earlier strains compare more favourably with few cuts than in the case of the late strains.

Wolfe (9) in America has quite recently shown that in the case of a series of pasture cuts made during the growing season, Italian rye-grass bears a higher relation to the hay yield than any other grass, the pasture amounting to as much as 93 per cent. of the hay.

is a grass which more than any other species has a remarkable aptitude for autumn and winter growth, and at all times of the year has an almost unique ability for "picking up" quickly under a system of repeated cutting or of intermittent grazing. The growth of the grass was also undoubtedly favoured on the monthly grazed plots by the intermittent manuring resulting from the sheep. It was noted at the time that this had a marked effect upon the subsequent growth of the rye-grass.

The figures, therefore, need cause no surprise and afford a significant commentary on the immense value of Italian rye-grass as a *pasture grass during such a period as it can be made to retain its hold on the ground*.

It will be obvious, however, from consideration of the figures in Tables I, II and III that the greater yield of the oft-grazed series (B) than of the totally rested series (C) or of the series partially grazed (A and D) has not been solely a function of the ability of Italian rye-grass to "pick up" quickly after grazing. It is to be observed (Table II) that the growth from cutting the corn to September 21st has been over 1,200 lb., while a cut made for the first time on October 27th is of the order 1,100 lb., and that made for the first time on March 30th is only about 1,000 lb (Table I). It follows, therefore, that new growth made subsequent to some date in October is not sufficient to compensate for the drying and rotting of the autumn growth.

The figures in Table III, moreover, indicate that the presence of a large amount of dead, or more or less dead, herbage actually tends to exert a retarding influence on growth—that is to say on the production of new and fresh herbage. It will be seen, for example, that the plots cut on September 21st, and from which the heavy autumn growth had consequently been removed, and on which the herbage had then been left to grow unhampered until March 30th, actually produced considerably more green (= fresh and reasonably new herbage), of Italian rye-grass on the crucial date, than the plots left ungrazed (and therefore carrying through the winter excess of dead and burned herbage) from corn harvest. This is an important and perhaps not generally realised effect of foggage and other rank growth that is in complete accord with observations made by one of us on grasslands in general at all seasons of the year.

Comparing the aggregate yields for the whole period (September to March) with those obtained on the crucial spring date (March 30th—see Table III) it will be noted that whereas the complete (series C) or almost complete (series A) resting of the sward from the time of corn harvest to the crucial date, gives rise to the greatest bulk of dry matter available on that date, yet this larger bulk will only have been rendered available by a serious sacrifice of valuable potential grazing during the late autumn and winter months—and this, altogether apart from considerations of the relative palatability and nutritive value of the larger bulk as compared with the smaller bulks on the more frequently grazed plots.

(2) *Autumn and winter yields*.—The yield data given in Table II are supported by "sheep day" figures. As before explained, the aim was to graze the plots bare at each grazing and to do this as quickly as possible. In the majority of cases the sheep were only in for two whole days of 24 hours, the number of sheep being increased in proportion to the herbage offering.

It will be noted in the first place (Table II) that the yield on the two series of plots (A and B) sampled on September 21st was high and in marked agreement. The number of "sheep days" of grazing was also decidedly high at this autumnal period—a result in entire agreement with previous experience. The monthly

variation in yield of dry matter (Table II) was very wide, and there was a gradual though not regular decrease from September to March—a decrease which in a general way is equally well shown by the “sheep day” figures. Confining attention to Italian rye-grass, it is worthy of note that the growth made subsequent to October 27th and up to the end of February (sum of monthly cuts in the dead season) was actually greater than that made in the comparatively good growing period from corn harvest (August 20th) to October 27th. The figures for December 30th show that for both total bulk and for bulk of Italian rye-grass as such a two month growing period (October 27th to December 30th : series D) has given over twice as much dry matter as a one month growing period (November 27th to December 30th : series B) and that these figures are reflected in the “sheep days” immediately following—48 days after the two months’ rest and 28 days after the one month’s rest. It is thus apparent that the winter keep from Italian rye-grass is very far from negligible, and that within limits which are quite appreciable and important the amount of herbage available on any particular date can be influenced by the system of grazing adopted.

TABLE II. *Autumn and winter yield data. Dry weights in lb. per acre. Average of a/ and b/ series.*

Scheme of grazing and sampling.	Series.	Date of cut, 1925 and 1926	Total yield of dry matter per acre.	Total yield of Italian rye-grass per acre.	Weight of rape, hardy green turnips and fescue.	Weight of weeds per acre.	No. of sheep days per acre at each grazing.
1st grazing ..	A.	21st Sept.	1256	875	157	224	370
2nd grazing ..	A.	29th March.	944	721	—	40	—
Sequential monthly grazings.	B.	21st Sept.	1248	907	137	204	320
	B.	27th Oct.	497	377	59	71	84
	B.	27th Nov.	602	383	38	181	56
	B.	30th Dec.	224	170	5	49	28
	B.	27th Jan.	383	340	2	51	28
	B.	27th Feb.	348	256	0	92	14
	B.	29th March.	209	127	—	15	—
1st grazing ..	D.	27th Oct.	1154	907	61	186	280
2nd grazing ..	D.	30th Dec.	482	389	6	87	48
3rd grazing ..	D.	29th March.	719	492	—	33	—

(3) *Yield at the crucial spring date (March 30th).*—It will be apparent from the data presented in Table III that in so far as total dry weight is concerned the greatest yield was obtained from the plots rested all the time from corn harvest (August 20th : series C), this was closely followed by the yield from those only grazed in September (series A), while those only grazed in October and December (series D) also yielded comparatively heavily. The series B grazed monthly from September 21st did not approximate in yield to the plots more leniently treated. Where only the yield of green (= relatively succulent and non-burned) Italian rye-grass is considered, it is found that the series grazed in September have substantially outyielded the plots left ungrazed from corn harvest,

TABLE III. Yield data at the crucial spring date (March 30th). Dry weights in lb. per acre. Average of a/ and b/ series. The percentage contribution of the different separations is also shown.

Number of previous grazings and month.	Series.	Date of cut.	Total yield of dry matter per acre.	Total yield of dry matter of green Italian rye-grass per acre.		Dry weight of weeds per acre.		Dry weight of burn per acre.*	
						Wt.	Per cent.	Wt.	Per cent.
		1926			per cent.				
One—Sept. ..	A.	29th March.	944	721	76	40	4	183	19
Six—Sept.-Feb.	B.	"	209	127	66	15	8	67	24
None ..	C.	"	1012	546	54	52	5	414	40
Two—Oct.-Dec.	D.	"	719	492	70	33	4	194	25

* In the main burned rye-grass, but contains also a small proportion of burned weeds.

while the series grazed in October and December now compare much more favourably with the totally rested plots than when the aggregate of weeds, green and burned Italian rye-grass is brought under review.

It has been previously shown by Stapledon and Davies (5) that herbage tends to become burned in proportion as it is mature, and thus as would have been expected the plots totally ungrazed from corn harvest contained by far the most and the highest proportion (40 per cent.) of burned material—nearly twice as much as any of the other plots. It is worthy of remark, however, that not only was the growth developed from December as badly burned as that from September, but judged by relative (percentage) figures the plots grazed monthly were also equally burned. This would in part have been due to the fact that the samples taken on March 30th would have included a certain proportion of stem (now burned) neglected from previous grazings; and in part to the fact that Italian rye-grass is capable of making appreciable growth even during March. It is perhaps at first sight surprising to find the plots grazed monthly (series B) actually containing a higher percentage of weeds, chiefly bent (*Agrostis vulgaris*) and daisies, than any of the others. This is a point which will be dealt with more fully when considering the question of palatability, but it appears to show that as the result of the extreme palatability of rye-grass leaf all through the period, rye-grass had all along been grazed more freely than weeds. This perhaps indicates that although the Italian rye-grass has "picked up" wonderfully after each grazing yet the plants of this grass have suffered more in persistency than have the weeds which had been relatively neglected all through the winter.*

It has been noted as a common phenomenon in connection with the herbage work in progress at the Station that most grasses tend to develop a "yellowing" as opposed to, and as well as, a burning during the winter. In the case of the present trials this yellowing was very apparent on the plots left ungrazed until the crucial date, and on those grazed only in September, while it was also slightly

* cf. Stapledon (4).

in evidence on those grazed both in October and December—there was practically no yellowing on the plots grazed at monthly intervals all through the experimental period. The yellowing of the herbage became most pronounced during March, and although probably not wholly due to attack by *Erysiphe graminis* would seem fairly definitely to be in part connected with the presence of this fungus.

The figures hereunder—based on actual clippings and dry weight determinations—indicate the extent of the yellowing on the different series of plots.*

C.	Ungrazed until the crucial date.	31	per cent.	of leaf yellowed.
A.	Grazed only in September.	32	"	" "
D.	Grazed in October and December	18	"	" "
B.	Grazed monthly (not analysed).	neg.	"	" "

Detailed consideration has been given to the question of both "burn" and "yellowing", because it will be shown in a subsequent section that they have an important bearing on the palatability or perhaps, what is of more moment, on the "eatability" of the herbage offering to sheep.

The evidence so far discussed, and having for the moment only regard to the amount of green Italian rye-grass herbage available at the crucial date, shows fairly conclusively that the best result will be forthcoming by grazing down the autumnal growth towards the end of September and then leaving the sward ungrazed until it is required. This would evidently be a far preferable practice to leaving the herbage as foggage and totally ungrazed from corn harvest to the crucial spring date.

It should be pointed out, however, that the field on which the experiment was conducted was on the whole well sheltered from the prevailing winds. On a more exposed situation where the herbage would be more liable to burn it might well be desirable to graze again subsequent to September—the yield from series D (grazed in both October and December) showing that such a procedure is not incompatible with a reasonably good yield at the crucial date.

II. RATIO OF LEAF TO STEM.

A number of confirmatory investigations have been conducted at the Station which have tended to show: (a) that the laminae or blades of the leaf (referred to as "leaf" in this paper) are of higher nutritive value (judged by chemical criteria) than the leaf sheaths (referred to as "stem" and included with stem proper in the various separations)†: (b) that sheep tend to graze leaf far more readily than they do stem.‡ It has, therefore, seemed desirable in connection with the present investigation to obtain as far as possible further critical evidence bearing on the leaf to stem relationships—these relationships are shown in Table IV.

Examination of the figures shows that the herbage present on the plots a month after corn harvest (*i.e.*, on September 21st) was of a relatively stemmy nature.

* "Yellowing" has of course to be considered as something quite different from burn, and has not been included with burn in any of the tables in which figures are given for "burn" as such.

† See, for example, Fagan and Jones (3), and Fagan and Evans (2).

‡ See, for example, Davies (1).

TABLE IV. *The percentage of leaf in the Italian rye-grass for each series for each cut.*

System of grazing and sampling.	Series.	Date of cut.	Percentage leaf in Italian rye-grass.	Percentage leaf of rye-grass in total bulk of dry matter.
Grazed twice.	A.	21st Sept., 1925	73.5	—
	A.	29th March, 1926	74.0	56.0
Grazed seven times.	B.	21st Sept., 1925	73.5	—
	B.	27th Oct., 1925	82.0	—
	B.	27th Nov., 1925	77.0	—
	B.	30th Dec., 1925	80.5	—
	B.	27th Jan., 1926	84.0	—
	B.	27th Feb., 1926	88.5	—
Grazed three times.	B.	29th March, 1926	83.5	56.0
	D.	27th Oct., 1925	76.0	—
	D.	30th Dec., 1925.	81.0	—
	D.	29th March, 1926.	81.5	57.0
Grazed once.	C.	29th March, 1926.	72.5	40.0

It will be seen that on the plots (series B) grazed monthly the tendency was in the main for the herbage to become progressively more leafy, which accords with previous investigations.

It is of particular importance to note that on the crucial date the series totally neglected (C) and that only grazed in September (A) gave rise to the least leafy herbage, while the herbage on the plots previously grazed in October and December (D) was practically as leafy as on those grazed monthly (B). When consideration is given to the contribution of rye-grass leaf to total produce from the plots the unsatisfactory state of affairs on the plots totally neglected (C) is at once apparent, while it is evident that in this respect there is nothing to choose between the remaining series of plots.

III. THE PALATABILITY TEST AT THE CRUCIAL GRAZING PERIOD (MARCH 30TH TO APRIL 13TH).

It is obvious that in relation to any investigations as to the carrying capacity of grasslands and the nutritive value of swards, the first necessity is to know precisely what the grazing animals eat and what preferences they show in respect of the medley of "eatable" substances offered to them at any particular time. Chemical or other investigations conducted on constituents of the herbage—taken in a general sample—which are in fact totally or almost totally neglected by stock are obviously at the best meaningless or at the worst actively misleading. An endeavour has therefore been made to ascertain what precisely the sheep have selected to eat when turned on the plots at the crucial period.

This section, therefore, has a decided interest not only in respect of the evidence actually obtained, but also on account of the novelty of the technique which has been employed with a view to the collection of that evidence.

Two methods of procedure have been adopted, namely, (1) to give sheep access to all the plots and to note their degree of preference for individual plots ;

and (2) to sample all the plots immediately before this grazing period and again at its termination, and to make critical botanical and chemical investigations on the two sets of samples.

(1) *Evidence of the sheep themselves.*

(a) *Procedure.*

On March 30th, the hurdles dividing the plots were taken away and 9 ewes and 16 lambs* were driven on to the plots at 10 a.m. The data to be collected consisted in observing at stated times the following particulars :—

- (i) The total number of ewes and lambs on any particular plot and whether merely resting or grazing.
- (ii) The number of ewes actually grazing.
- (iii) The number of lambs actually grazing.

On the first day an observation was taken half an hour after the sheep were turned on to the plots and afterwards at every hour throughout the day up to 7 p.m. For the remaining days of the grazing period, observations were taken at three-hourly intervals, namely, at 7 a.m., 10 a.m., 1 p.m., 4 p.m., and 7 p.m. When considering the evidence thus obtained the data indicated that the grazing period fell fairly naturally into two more or less distinct phases, namely :—

(i) Tuesday, March 30th, to Thursday, April 1st : *giving 3 days.*

(ii) Monday, April 5th, to Saturday, April 10th : *giving a further 6 days.*

The data obtained from the observations made on the sheep were dealt with as follows :—

The number of ewes grazing a particular plot as indicated by the observations throughout the day were totalled, and the number divided by the number of observations made on that day, this giving an average figure for the day. These daily averages were then totalled for each part of the critical grazing period. It was felt that this method would give a preference figure for each series, which would afford a good indication of the degree of the palatability and eatability resulting from each treatment. The observations on the ewes resting and on the lambs were dealt with in the same way.

(b) *Discussion.*

In Table V are given the preference figures which were arrived at by totalling the average observation figures for (a) the first part of the grazing period which consisted of three days ; (b) the second part of the period which covered the fourth to the ninth day ; and (c) the total preference figures for each series of plots over the whole crucial grazing period.

Since the lambs were very young and their position on a plot at any particular time could not be considered sufficient indication that they were grazing that plot to any great extent, it is probable that the lamb evidence should not be taken into very serious account when examining the data as a whole, and that the main attention should be paid to the ewes. Again, it is probable that not much weight can be attached to the figures indicating the total number of ewes or lambs actually on a particular plot at the time of making

* The average weight of the ewes was about 130 lb., and of the lambs about 35 lb., while the average age of the lambs was about 5 weeks.

the counts, as these figures include the numbers that were resting as well as grazing.* It was thought at the time of making the observations that records relative to the number of sheep resting on a series would perhaps be significant, in that they might give some indication as to the plots the sheep had been grazing, but the register showed that the sheep did not necessarily settle down on the plot on which they had just been feeding.

The figures relative to the number of ewes grazing (Table V) indicate that during the first three days there was a decided preference shown for the plots which had been previously grazed in October and December, figures which are in a broad way confirmed both by the lamb data and by the number of ewes and lambs resting on the plots, while the plots receiving least attention were those which had been totally ungrazed, and those which had only been grazed in September. These figures are in complete accord with what would have been expected from a consideration of the yield, burn, "yellowing" and stem and leaf data previously discussed. The totally ungrazed plots contained the greatest bulk and the greatest relative amount of burned material as well as a considerable amount of "yellowed" rye-grass. Thus, although they yielded a large amount of green rye-grass, this was to a great extent rendered inaccessible, and consequently as long as other green herbage was readily available these plots were largely neglected—a state of affairs in complete accord with observations previously made at the Station.†

It is of considerable importance to note that apparently a greater preference was shown for the plots having on them three months' growth (series D) than for those having only one month's growth (series B). The amount of green rye-grass was much greater on the former plots, while although the amount of burned material was also greater the proportion was about the same as on the more continuously grazed series. It would seem probable, therefore, that provided herbage is green and succulent and still immature it will be taken with nearly as much avidity as even more succulent herbage that requires very close grazing to acquire—again emphasising the importance of accessibility.

By the second part of the grazing period (after the third day) it is evident that the green herbage on the plots most fancied during the first three days (*i.e.*, series D previously grazed in October and December) was running short, consequently the ewes, and for that matter the lambs also, now started paying marked attention to that series only grazed in September (series A): plots which it is to be noted contained the most green rye-grass of all, and were much less burned than those left entirely ungrazed (series C).

Perhaps the most significant fact brought out by these records is that the sheep for a period of as long as nine days still showed an altogether greater preference for the plots grazed monthly and only offering 127 lb. of green rye-grass per acre than they did for those left totally ungrazed, although these latter offered as much as 546 lb. of green rye-grass—leafage which, however, was relatively adult and largely rendered inaccessible by excess of burned material. It is to be further noted that the plots chiefly preferred were those which contained the highest ratio leaf to stem of Italian rye-grass and also the greatest proportion of Italian rye-grass leafage to the total bulk of material offering on the plots.

* Had it been possible to set up the experiment with plots an acre or more in size it is probable that the resting figure would have had decided significance—provided no attention was paid to the position where the sheep actually "camped" at night.

† See Stapledon and Davies (5) and Davies (1).

TABLE V. *Preference figures for the different series of plots for (a) the first three days of the crucial grazing period ; (b) the second part of the period ; and (c) the whole crucial grazing period.*

Pre-treatment.	Series.	Total no. of ewes on plot.	Number of ewes grazing.	Total no. of lambs on plot.	Number of lambs grazing.
(a)					
Grazed only in September	A.	2.20	1.30	5.40	5.05
Grazed six times monthly	B.	7.65	2.90	13.70	5.20
Totally ungrazed ..	C.	3.35	2.35	5.45	3.90
Grazed in Oct. and Dec.	D.	10.05	4.75	15.20	5.65
(b)					
Grazed only in September	A.	8.75	8.15	11.35	10.75
Grazed six times monthly	B.	23.10	5.40	27.55	5.40
Totally ungrazed ..	C.	3.50	2.65	6.55	5.60
Grazed in Oct. and Dec.	D.	13.10	3.60	21.30	2.95
(c)					
Grazed only in September	A.	10.95	9.45	16.75	15.80
Grazed six times monthly	B.	30.75	8.30	41.25	10.60
Totally ungrazed ..	C.	6.85	5.00	11.90	9.50
Grazed in Oct. and Dec.	D.	23.15	8.35	36.50	8.60

(2) *Evidence by comparing the samples taken before the grazing period with those taken afterwards.*

(a) *Procedure.*

As previously stated the plots were sampled by the usual procedure before the sheep were turned in. After the collection of the preference data for the sheep the plots were grazed for a further six days and sampled again on April 13th. It is obvious of course that a comparison between the two sets of samples cannot give an absolute picture of what the sheep eat and what they neglected, for there would have been a certain, and by no means negligible, amount of growth during the period March 30th to April 13th. It will, however, be apparent from the discussion which follows that even after making conservative allowance for this disturbing factor the comparison is highly suggestive and in full accord with the sheep preferences previously discussed.

(b) *Discussion.*

When the samples were taken after grazing (April 13th), it was found that the series (B) grazed monthly prior to the crucial date had been eaten so closely during the crucial period that it was quite impossible to harvest a sample from the plot. Data for the remaining series are set out in Table VI (page 18).

The most striking feature of the results is perhaps that in every case the amount of weeds had quite substantially increased during the 14 day grazing period. This showed not only that there had been growth during this period,

but that the rye-grass which in all cases had registered a substantial decrease was evidently much preferred by the sheep to the weeds.* It is significant in this connection that the weeds had increased most on the plots (series C) least grazed by the sheep.

With regard to the rye-grass itself, the figures afford striking confirmation of the statement frequently made in previous reports on the work of the Station, and implied by the behaviour of the sheep themselves on the plots under review, namely, that sheep show a very decided preference for leaf. Not only has leaf been altogether more heavily grazed than stem on all the plots, but it has been most heavily grazed on the plots carrying the least mature leafage (series D, and, of course, series B). The figures in the table as to leaf could not have been materially affected by growth, indeed, if so influenced, the effect would have been to make the figures as shown constitute an underestimate rather than an overestimate of the sheep's preference for leaf. The same preference is shown by the difference in the percentage leaf of the Italian rye-grass before and after grazing as illustrated by the figures hereunder :—

<i>Percentage of leaf in Italian rye-grass.</i>			
<i>Before grazing.</i>			<i>After grazing.</i>
<i>March 30th.</i>			<i>April 13th.</i>
Series A	..	74	55
„ C.	..	72	56
„ D.	..	81	61

The fact that stem has increased to a slight extent on the little frequented series C, shows that there was slight growth of rye-grass during the 14 day grazing period, but shows by that much the more conclusively by comparison with the figures for less mature herbage (series A and D) that stem tends to be grazed in proportion as it is immature. The figures as to burn indicate that this element of the herbage although by no means entirely neglected, is only taken by sheep to a comparatively small extent, at all events as long as green and more succulent herbage is available. It is interesting to note that the greatest reduction in burn occurred on the plots previously grazed in October and December, plots for which sheep showed the greatest initial preference, suggesting that the burn to a large extent was incidentally eaten in consequence of the sheep striving after the attractive green herbage on these plots.

Owing to the fact that growth took place during the crucial grazing period, it is impossible to estimate accurately the bulk of material actually eaten in those 14 days. In Table VII data have, however, been presented which show the differences in yield of the plots before and after grazing, and which also show the difference after making an adjustment for the growth taking place during the grazing period. The growth on series B for a month, February to March, was 209 lb. dry matter per acre. It has been assumed that the growth on all the plots March 30th to April 13th would have been 200 lb. plus the increase of weeds actually recorded. From the evidence afforded on the plots at the time this may be regarded as a very generous allowance: the differences in yield are then worked out in sympathy with this adjustment.

* The weeds were chiefly bent grass (*Agrostis vulgaris*) and daisies, and it was noted at the time that at this period the daisies were beginning to make appreciable growth.

Reference to the table indicates that the results are in precisely the same direction, though different in magnitude, whether the adjusted or non-adjusted figures are considered.

The most interesting conclusion to be drawn is as follows:—"During a comparatively restricted grazing period the amount of the available material actually grazed on a series of plots of one and the same species will be in inverse proportion to the gross amount of that material actually offering."

This fact is well shown by the proportion of the available herbage which was actually eaten by the sheep on each series of plots—these figures may be regarded as a measure of relative palatability. When the figures as set out below are compared with the number of grazings each series received, it would seem that palatability is in direct proportion to the number of grazings between corn harvest and spring.

Series.	Number of grazings (excluding critical period).	Relative palatability.
B.	6	100
D.	2	55
A.	1	35
C.	0	14

This indicates clearly the effect the different treatments had on the palatability of the Italian rye-grass at the time of the crucial grazing period.

With reference to the different plots under review the figures in Table VII show fairly conclusively that during the 14 days grazing the greatest amount of material was removed from the series previously grazed in October and December (D), and that previously grazed in September only (A)—the two series which the sheep register also indicated as having held grazing sheep for the greatest number

TABLE VI. To show the difference in yield of the various components of the herbage before grazing (March 30th) and after a period of grazing (April 13th). Dry matter in lb. per acre.

Pre-treatment before crucial date.	Series.	Before and after grazing, and difference.	Italian rye-grass.		Weeds.	Burn.
			Stem.	Leaf.		
Ungrazed.	C.	Before ..	145	401	51	400
		After ..	165	213	122	363
		Difference ..	+ 22	—288	+ 71	— 37
Grazed in Sept.	A.	Before ..	192	529	39	182
		After ..	158	190	74	200
		Difference ..	— 34	—339	+ 35	+ 18
Grazed in October and December.	D.	Before ..	92	400	30	180
		After ..	60	96	47	115
		Difference ..	— 32	—304	+ 17	— 65

+ = Increase during period of grazing.

— = Decrease " " "

TABLE VII. To show (a) the actual gross yields of dry matter before and after grazing; (b) the relative yields before grazing; (c) the adjusted yields after grazing; (d) the presumable amount of material eaten by the sheep by difference and on the adjusted figures; and (e) the percentage of available material eaten by difference and on adjusted figures. Dry matter in lb. per acre.

NOTE.—For method of adjustment see text.

Pre-treatment before crucial date.	Series.	Yield before grazing.	Relative yield, highest yield = 100.	Yield after grazing.		Amount presumably eaten by sheep during grazing period.		Percent. of total herbage available eaten by sheep.	
				Actual.	Adjusted.	By difference	Adjusted.	By difference.	Adjusted.
Grazed monthly ..	B.*	209	21	neg.	neg.	209†	209†	100†	100†
Grazed in Oct. and Dec. ..	D.	719	71	302	103	417	634	55	85
Grazed in September ..	A.	944	94	613	378	331	566	35	60
Ungrazed ..	C.	1012	100	867	596	145	416	14	41

* Plots so closely grazed that it was quite impossible to harvest a sample after the grazing period.

† On the assumption that absolutely all the herbage on the plot was in fact eaten.

of hours. On the adjusted figures the plots left ungrazed from corn harvest provided more keep to the sheep during the grazing period than those grazed monthly: this is not in agreement with the evidence of the sheep register. It is probable that the sheep register and the non-adjusted figures come nearer the truth, for it is exceedingly unlikely that plots bearing a mass of burned and dead herbage would in fact have put on the 200 lb. growth conceded to all plots alike in the adjustment. Taking the evidence of the yields and the sheep register together it may, however, be concluded that the oft-grazed series of plots hold sheep by virtue of an attractiveness over and above the amount even of green herbage offering: the herbage was evidently so succulent and immature that sheep frequently were "willing" to graze slowly on these plots rather than graze rapidly elsewhere.

IV. THE CHEMICAL COMPOSITION OF THE PRODUCE FROM THE SEVERAL PLOTS.

For the purpose of discussion, the average figures for the sub-plots are taken, for although, as has been previously explained, the seeds mixture varied, the difference in chemical composition between the produce of the duplicate sub-plots was so small, that it is unnecessary to consider them separately.

It will be convenient first to deal with the aggregate produce from the plots, and then to consider the chemical characteristics of the various separations.

(1) *The monthly cuts (= series B).*

(a) "*Bulk sample.*"—The composition of the dry matter and the weight per acre of the several constituents for each monthly cut is set out in Table VIII.

It will be noted that the composition of the dry matter in September (when the yields were highest), (see Table II p. 10) is poorer in protein and higher in fibre than any of the other cuts: this cut represented growth from August 20th, and consisted of a relatively mature product. With the decrease in yield which follows on the waning of the growing season, and on the shorter intervals allowed for growth, the percentage of both crude and true protein increases and the produce becomes less fibrous. In order to facilitate comparison the main results have been plotted as graphs and are shown in Figures 1 and 2.

Reference to Figure 1 shows that the percentage of crude and true protein and also of silica-free ash is lower in December than in both November and January, while the curve for fibre shows a distinct peak at this period. From December onwards, the percentage of crude protein increases gradually, but the true protein shows less regularity. The March growth is characterised by a low yield of dry matter (see Table III), rich in protein but poor in silica-free ash.

A comparison of the curves for true protein and fibre respectively, is of interest, for it will be observed that when there is a tendency for one of these constituents to increase the other decreases.

The variation in the percentage of mineral constituents is shown in Figure 2. The seasonal variations in the silica-free ash and chlorine are of a similar type. It will be observed that while the phosphoric acid increases in the second cut the lime shows a corresponding decrease, though the rise and fall in the next three cuts is very similar for both constituents. In the September growth the lime is distinctly in excess of the phosphoric acid, but in the succeeding four cuts the phosphoric acid is slightly in excess of the lime, the February and March cut being again higher in the latter. Of the mineral constituents determined, the phosphoric acid is the only one which shows a decrease in the February cut.

TABLE VIII. To show (1) the composition of the dry matter for each of seven monthly cuts; and (2) the yield in lb. per acre of each of the constituents. Series B.

Date of sampling	21/9/25.		27/10/25.		27/11/25.		30/12/25.		27/1/26.		27/2/26.		29/3/26.		Total yield for seven months.
	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	
Crude protein	..	117.0	15.00	74.6	15.34	92.3	13.09	29.3	14.62	57.4	14.91	51.9	15.75	33.0	455.5
True protein	..	109.0	10.41	51.8	13.34	80.3	11.31	25.4	13.34	52.4	12.37	43.0	14.03	29.3	391.2
Fibre	..	385.0	29.58	147.0	25.64	154.0	29.52	67.0	25.00	98.0	26.33	92.0	26.65	56.0	1089.0
Silica-free ash	..	84.0	7.21	35.9	6.19	37.3	5.68	12.7	6.14	24.1	8.13	28.3	4.78	10.0	232.3
Phosphoric acid	..	7.4	0.83	4.1	0.75	4.5	0.73	1.6	0.80	3.1	0.73	2.5	0.62	1.3	24.5
(P ₂ O ₅)	..	12.9	0.80	4.0	0.73	4.4	0.69	1.5	0.74	2.9	0.76	2.6	0.72	1.5	29.8
Lime (CaO)	..														

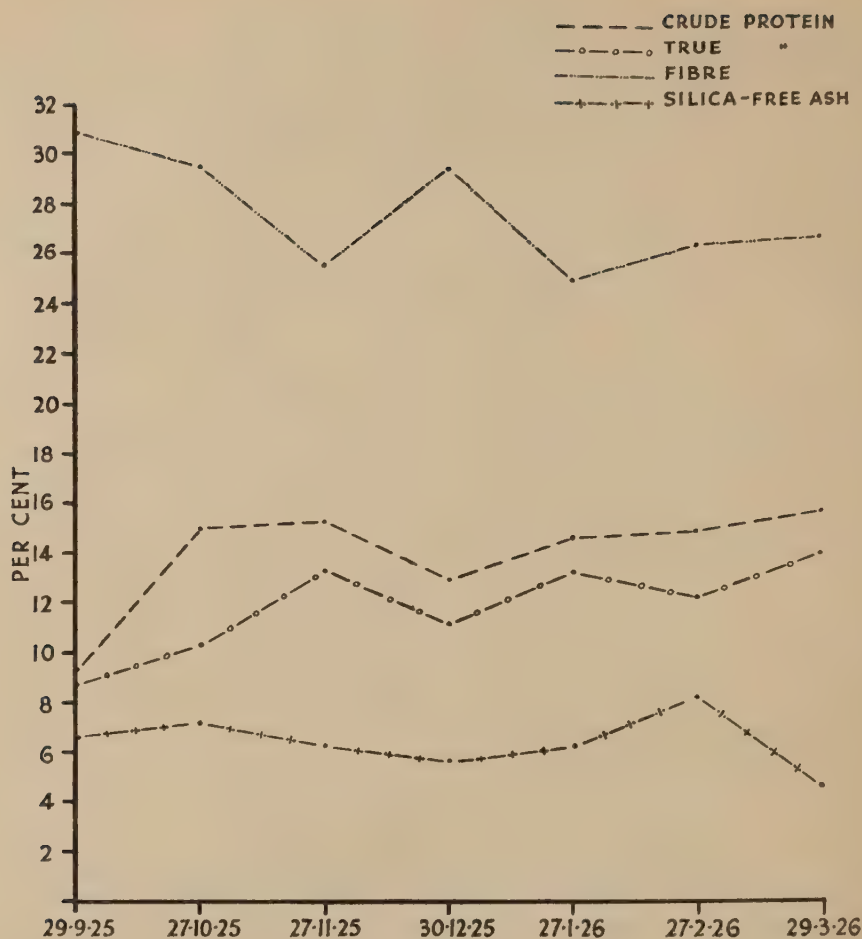


Fig. 1. Graph showing variation in protein, fibre and silica-free ash of the bulk sample during period September—March.

The range of the seasonal variation and the period at which the maximum and minimum content of the different mineral constituents occur are as follows :

Constituent.	Max. content.	Min. content.	Percentage variation.
Silica-free ash.	February.	March.	41
Phosphoric acid.	October.	September.	28
Lime.	September.	December.	33
Chlorine.	October.	February.	54

From the above it is seen that the chlorine and ash content show the widest variation, and the phosphoric acid least.

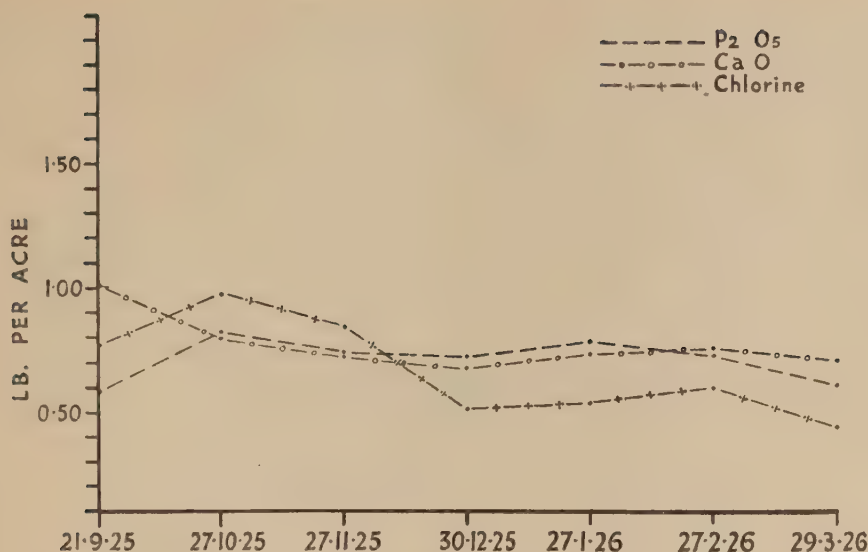


Fig. 2. Graph showing variation in mineral content of the bulk sample during period September—March.

The results in Table VIII giving the yield of nutrients and those in Tables II and III giving the total yield of dry matter, indicate that dry matter alone is not a safe guide to the supply of nutrients. Thus it is seen that although the yield of dry matter in September (relatively mature growth) is more than double that of November, yet the difference in yield of protein is only 20 per cent. in favour of the September growth, while the fibre is 60 per cent. higher in September than in November.

It is to be noted that under this system of grazing (monthly), the weight of nutrients produced in March is only slightly better than that produced during December, the lowest yielding month,—showing again that rye-grass has maintained a measure of productivity all through the winter.

(b) *The separations.*

In this section the seasonal variation in the chemical composition of the separations (stem and leaf of Italian rye-grass and weeds) will be dealt with, and the effect of the varying proportions of these on the composition of the bulk sample will be considered.

The results of the analyses are set out in Table IX.

Unfortunately a complete examination of the stem portion was not always possible, as in the majority of cuts the weight was too small, the amount available being reserved for an examination of its mineral content. Such figures as are available, however, are in complete agreement with the earlier work, and show the leaf to be richer in crude and true protein than the stem, and lower in fibre.

In the first three cuts the protein content of the stem is seen from the table to fluctuate more than that of the leaf; the minimum percentage which is reached in the stem in December being followed by a gradual increase, so that in

TABLE IX. To show the percentage composition of stem and leaf of Italian rye-grass, weeds, and burn (for the March cut) in the monthly cuts November to March. Series B.

Date of sampling.	Constituents.	27/11/25.			30/12/25.			27/1/26.			27/2/26.			29/3/26.		
		Stem. *	Leaf. *	Weeds. †	Stem.	Leaf.	Weeds.	Stem.	Leaf.	Weeds.	Stem.	Leaf.	Weeds.	Stem.	Leaf.	Weeds.
Ether extract	..	3.30	4.92	2.95	—	4.05	2.95	—	4.18	3.48	—	4.87	—	—	4.70	—
Crude protein	..	14.62	19.34	12.31	9.06	17.63	8.56	11.44	17.75	9.62	14.50	22.94	10.37	—	21.12	16.50
True protein	..	10.50	16.21	9.50	—	12.99	—	—	16.59	—	—	20.46	9.37	—	16.34	14.50
Fibre	..	28.30	20.84	31.60	—	26.29	31.00	—	24.70	28.03	—	20.33	—	—	17.13	—
Ash	..	8.07	10.42	12.47	8.13	14.18	17.53	8.77	13.73	19.47	12.00	15.95	23.60	8.02	9.49	8.80
Soluble carbohydrates	..	45.71	44.46	40.67	—	37.85	39.96	—	42.12	39.40	—	35.91	—	—	47.60	—
Silica (SiO ₂)	..	3.05	3.91	7.47	3.63	7.79	12.53	3.77	7.55	15.56	5.00	7.25	14.70	0.96	1.81	2.88
Silica-free ash	..	5.02	6.51	5.00	4.50	6.39	5.00	5.00	6.18	3.91	7.00	8.70	8.90	7.06	7.68	5.92
Phosphoric acid (P ₂ O ₅)	..	1.31	0.88	0.71	0.66	0.82	0.51	0.71	0.85	0.57	1.30	0.96	0.60	0.89	0.77	0.85
Lime (CaO)	..	0.58	0.73	1.05	0.53	0.69	0.90	0.61	0.71	—	0.68	0.81	0.72	0.73	1.03	1.25
Chlorine (Cl)	..	—	1.09	—	0.60	0.69	0.30	—	0.62	—	—	1.11	—	—	1.01	—
Nitrogen (N)	..	2.33	3.10	1.96	1.45	2.82	1.37	1.83	2.84	1.57	2.40	3.67	1.66	—	3.38	2.64
Burn.	..	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* Stem and leaf are of Italian rye-grass only.

† "Weeds" are chiefly bent (*Agrostis vulgaris*) and daisies.

February the protein has almost reached the amount found in November, when it was at its maximum. In the leaf, on the other hand, the protein in the first three cuts is fairly constant, but a rapid rise takes place in February, followed by a slight fall in March. The fibre of the leaf after a rise in December steadily falls in each of the successive cuts. In the March cut, the results show that in both the stem and leaf the silica-free ash is only slightly lower than the amount found in February, which was the maximum. This is contrary to what would be expected from the analysis of the bulk sample, for reference to Table VIII shows the silica-free ash to be at its minimum in this cut. However the low percentage of silica-free ash in the burn (see Table IX), which contributes to the bulk sample, explains this apparent contradiction.

Further comparison is facilitated by reference to Figure 3 in which some of the chief results have been plotted.

The effect of weeds and burn on the phosphoric acid content of the bulk sample is seen on comparing the curves for this constituent in Figures 2 and 3.

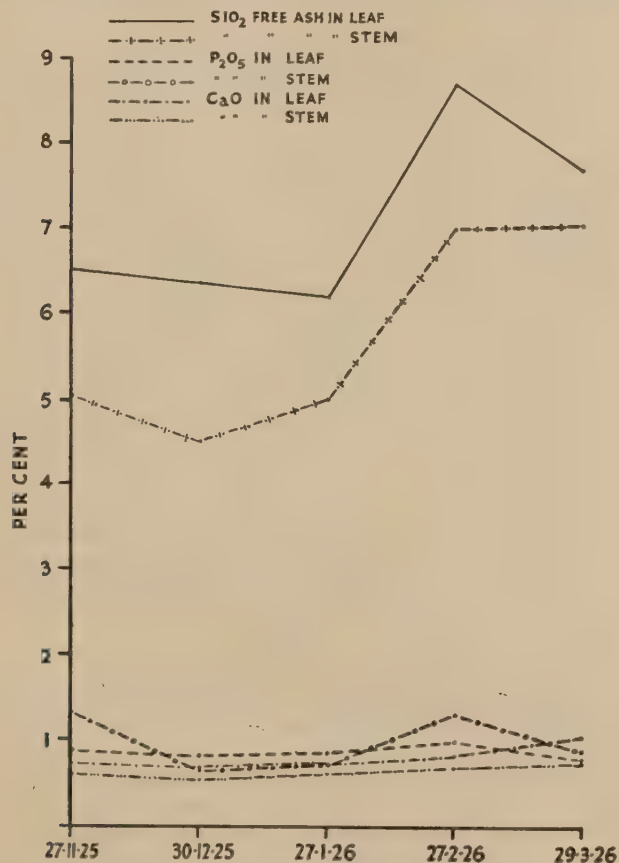


Fig. 3. Graph showing variation in mineral constituents of stem and leaf during period November—March.

From November to January they are in general agreement, but in February while the phosphoric acid content of the bulk sample falls, that of the stem and leaf of Italian rye-grass rises. Table II supplies the explanation of this, for approximately 25 per cent. of the bulk sample in February is composed of weeds, and these are shown (in Table IX) to be inferior to Italian rye-grass in phosphoric acid. Again the inclusion of burn accounts largely for the low percentage of phosphoric acid in March, though both stem and leaf show a decrease in this constituent compared with February.

The stem is poorer than the leaf in lime, at all periods, though the variation is very similar in both (see Figure 3). From December to March, there is a steady rise of lime in both stem and leaf, but this is more pronounced in the latter. The contradictory behaviour of the lime in the bulk sample at this period (Figure 2) is again due to the fact that it contains a considerable amount of burn (24 per cent.) which is comparatively poor in lime.

It will be noted that the lime is lower than the phosphoric acid in both stem and leaf, with the single exception of the March cut, when the leaf is considerably richer in lime.

The weeds growing on the plots show considerable variation in composition throughout the period. Compared with Italian rye-grass, they are poor in protein and high in fibre, though they are fairly rich in certain mineral constituents such as lime.

The results of the chemical analysis of the separations have been calculated into pounds per acre, and are given in Table X. In view of the fact that sheep have been shown to have a preference for leaf over stem, the results in the above table are of interest in that they indicate the amount of nutrients actually supplied by the leaf. That the monthly contribution of the leaf to the weight of nutrients varies would be expected, both from the difference in its yield and composition. The actual amount contributed, as well as the variation, is apparent from the fact that from 61 to 83 per cent. of the total protein and 58 to 80 per cent. of the total silica-free ash in the different monthly growths are supplied by the leaf. The sheep by this selective grazing obtain a food richer in protein and silica-free ash than if they partook impartially of the total bulk of herbaceous material on the plot, while the ratio of the constituents to each other in the leaf is different to that found either in the whole rye-grass plant, or in the aggregate of rye-grass, weeds and burn.

The contribution of burn to the nutrients in March is small, but the fact previously pointed out that this portion is unpalatable renders it of little, if any, value. This point will be discussed more fully when the produce from the March sampling of all the plots is considered.

(2) *Cuts made in October, December and March (series D).*

The results of the chemical analyses of the growth made between August and October ; October and December ; and December and March respectively are shown in Table XI.

It will be seen from the table that the chemical composition of the March cut is superior in protein and less fibrous than either of the others, but in silica-free ash the October cut is the richest, the greatest difference in the mineral constituents occurring in the chlorine.

A comparison of the above figures (Table XI) with those for the monthly cuts (see Table VIII) is of interest. It will be noted for example that the

TABLE X. To show the yield in lb. per acre respectively of stem and leaf of Italian rye-grass, weeds and burn (for the March cut) of the various nutrients contributing to the bulk for the monthly cuts November to March. Series B.

Date of sampling.	27/11/25.				27/1/26.				27/2/26.				29/3/26.			
	Stem *	Leaf *	Weeds †	Total	Stem	Leaf	Weeds	Total	Stem	Leaf	Weeds	Total	Stem	Leaf	Weeds	Total
Crude protein ..	13.00	57.0	23.0	93.0	3.00	24.00	4.30	31.30	6.50	52.0	3.90	62.4	—	22.50	2.60	—
True protein ..	9.30	48.0	17.5	74.8	—	18.00	—	—	—	49.0	—	—	—	17.40	2.30	—
Fibre ..	25.00	61.0	58.0	144.0	—	26.00	16.00	—	—	73.0	11.40	—	—	18.30	—	—
Silica-free ash ..	4.40	19.2	9.2	32.8	1.50	8.70	2.50	12.70	2.80	18.2	1.60	22.6	—	8.20	0.93	11.83
Phosphoric acid (P ₂ O ₅) ..	1.16	2.6	1.3	5.0	0.20	1.10	0.26	1.56	0.40	2.5	0.23	3.1	—	0.80	0.13	1.30
Lime (CaO) ..	0.51	2.1	1.9	4.5	0.18	0.94	0.50	1.60	0.34	2.1	—	—	—	1.10	0.18	1.73
Potash (K ₂ O) ..	2.75	10.9	4.3	17.9	1.00	3.30	1.10	5.40	1.86	10.4	1.00	13.2	—	4.26	—	—

* Stem and leaf are of Italian rye-grass only.

† "Weeds" are chiefly bent (*Agrostis vulgaris*) and daisies.

TABLE XI. *To show the chemical composition of the bulk sample for growths cut in October, December and March. Series D.*

Constituents.	Growth from August to October.	Growth from October to December.	Growth from December to March.
Ether extract	3.15	3.00	3.90
Crude protein.. .. .	11.90	11.08	12.74
True protein	9.09	9.46	11.90
Fibre	30.61	31.24	24.51
Ash	10.92	13.33	8.25
Silica-free ash	6.85	4.94	5.01
Phosphoric acid (P_2O_5)	0.77	0.61	0.58
Lime (CaO)	0.99	0.77	0.78
Chlorine (Cl.)	1.10	0.33	0.51
Nitrogen	1.90	1.79	2.04

two months' growth August-October is not as rich in crude protein or true protein as the one month's growth September-October, while the two months' growth contains more fibre than that of the one month. The same is true of the two months' growth October-December and the one month's growth November-December. The comparison holds equally well in respect of the protein as between the growth December-March and that of February-March ; in this case, however, the fibre content is slightly higher in the produce of the one month's growth.

These results are confirmatory of those previously reported, and indicate clearly the higher concentration in nutrients of young and immature growth compared with that even slightly older and but little more mature.

The fact that the growth August-October (Table XI) was slightly richer in protein than that of August-September (Table VIII) shows that there was a very appreciable production of new and fresh herbage during the period September-October—enough new growth, in fact, to more than compensate (from the point of view of composition), for the maturing of that developed up to the end of September.

The total nutrients supplied by the three cuts under consideration have been calculated as before, and the results are given in Table XII.

TABLE XII. *To show the yield of nutrients in lb. per acre for the produce cut in October, December and March. Series D.*

Constituents.	Growth from August to October.	Growth from October to December.	Growth from December to March.
Crude protein.. .. .	137.4	53.4	91.6
True protein	105.0	45.6	85.6
Fibre	350.0	151.0	176.3
Silica-free ash	79.0	23.8	36.0
Phosphoric acid (P_2O_5)	8.9	2.9	4.0
Lime (CaO)	11.4	3.7	5.6

Although as previously shown (see Tables II and III) the yield of produce for the period August-October (represented by one cut) is almost as great as that for the period October-March (represented by two cuts) yet the weight of crude protein supplied in March is only about 33 per cent. lower than in October, while the weight of fibre on the other hand is 50 per cent. higher.

(3) *Cuts made in September and March (series A).*

The data in respect of these growths are set out in Table XIII.

TABLE XIII. *To show the chemical composition and yield of the several nutrients in lb. per acre for cuts made in September and March. Series A.*

Constituents.	Growth between August and September.	Growth between September and March.	Yield of nutrients between August and September.	Yield of nutrients between September and March.
Ether extract	3.10	3.91	—	—
Crude protein	9.93	12.71	125.0	120.0
True protein	8.28	11.71	104.0	110.6
Fibre	31.50	23.32	396.0	220.0
Ash	9.31	8.91	—	—
Soluble carbohydrates	46.15	57.15	—	—
Silica (SiO ₂)	2.81	2.68	—	—
Silica-free ash	6.50	6.23	81.6	58.8
Phosphoric acid (P ₂ O ₅)	0.58	0.70	7.3	6.6
Lime (CaO)	1.16	0.90	14.5	8.5
Chlorine (Cl.)	0.84	0.90	—	—
Nitrogen	1.59	2.03	—	—

The period August-September was of course favourable to rapid growth, while that of September to March, although much longer, was not conducive to vigorous development. How much more favourable to growth was the former period is shown by the fact that the yield of dry matter in September was about 25 per cent. higher than that of March (see Tables II and III). The chemical composition of the March cut although representing six months' growth was, however, richer in protein and less fibrous than the month's growth taken in September. This comparison serves to emphasise how rapidly herbage falls off in nutritive value at a period when it is making quick growth, and is left ungrazed. When on the other hand growth is at a low ebb, deterioration is not nearly so rapid, for the root leaves continue to elongate slowly and do not quickly age, in any event they do not burn as quickly as "stem leaves," while during periods of slow growth stem development is always at a minimum.

The results in Table XIII show that the total yield of protein from the September cut is only 4 per cent. higher than that of the March cut, whereas the fibre is about 45 per cent. greater. The mineral content on the other hand is considerably higher in September, as shown alike by the silica-free ash and lime.

The comparisons in this and the previous section, between long and short periods for growth under comparatively similar conditions, and between short periods for growth under very favourable conditions with long periods under

unfavourable conditions, are decidedly illuminating, and show in a conclusive manner the relation of the condition of the herbage at any particular time to its nutritive value. The data under discussion demonstrate that the condition of the herbage at any time is not only a function of the climate influencing growth, but also of the intensity of grazing and the preference of the animals having access to the herbage.

- (4) *Aggregate yield of nutrients under the different systems of cutting (series A, B, C and D).*

The total yields of dry matter under the different systems of cutting have been given in Table I, and previously discussed. The chemical data are set out in Table XIV.

TABLE XIV. *To show the aggregate yield of nutrients in lb. per acre from the four series of plots differently treated during the period August-March. Series A, B, C and D.*

Constituents.				
	Series C.	Series A.	Series D.	Series B.
	Grazed in March only.	Grazed in Sept. and Mar.	Grazed in Oct., Dec. and Mar.	Grazed at seven monthly intervals.
Crude protein	121	245	282	456
True protein	114	214	236	391
Fibre	246	616	677	1089
Silica-free ash	53	140	139	232
Phosphoric acid (P_2O_5) ..	7	14	16	24
Lime (CaO)	8	23	21	30

Comparing the figures in Table XIV with those in Table I it will be apparent that both sets of figures are in agreement, namely, that the aggregate yield of both dry matter and nutrients is greatest on the plots most frequently grazed. In the main, frequent cutting has had a greater effect on the yield of crude protein than on the dry matter, as shown by the following statement:—

	<i>Relative yields.</i>	
	<i>Dry matter.</i>	<i>Crude protein.</i>
Plots wholly rested until March ..	100	100
Plots grazed seven times	347	377

It is to be particularly noted that the aggregate yield of fibre is very much higher on the plot grazed monthly than on any of the other series, largely due to the high percentage of weeds on this plot.

The amount of digestible fibre would, however, be considerably higher on the plot constantly grazed, owing to the fact that the growth of Italian rye-grass on this plot would have been kept in a younger and more succulent condition than on the others. For it has been shown at Cambridge* that the digestibility of the fibre present in young grasses may be as high as 80 per cent.

* See Woodman (10).

The figures for phosphoric acid and lime give some indication of the amount of these important ingredients removed from the soil under the different systems of management, and emphasise the importance of adequate manuring particularly where the grazing is heavy.

(5) *Cuts made on the crucial spring date—March 30th (series A, B, C and D).*

All the plots were sampled on March 30th prior to the commencement of the crucial grazing period, and as before, chemical analyses were conducted on the "bulk samples" and on the various separations.

(a) *The bulk samples.*

The chemical composition of the "bulk samples" and the yield of the chief ingredients are shown in Table XV.

TABLE XV. *To show the chemical composition and yield in lb. per acre of the chief ingredients for the bulk herbage produced by the several series of plots on the crucial spring date—March 30th. Series A, B, C and D.*

Previously cut in	Series C.		Series A.		Series D.		Series B.	
	Untouched.		September.		Oct. and Dec.		Monthly.	
Constituents.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.
Ether extract ..	3.41	—	3.91	—	3.90	—	3.03	—
Crude protein ..	12.00	121.4	12.71	120.0	12.74	91.6	15.75	33.0
True protein ..	11.31	114.5	11.71	110.6	11.90	85.6	14.03	29.3
Fibre ..	24.28	245.7	23.32	220.3	24.51	176.3	26.65	56.0
Ash ..	9.59	—	8.91	—	8.25	—	8.56	—
Soluble carbo- hydrates ..	50.72	—	51.15	—	50.60	—	46.01	—
Silica ..	4.36	—	2.68	—	3.24	—	3.78	—
Silica-free ash ..	5.23	52.9	6.23	58.8	5.01	36.0	4.78	10.0
Phosphoric acid	0.65	6.6	0.70	6.6	0.58	4.2	0.62	1.3
Lime ..	0.77	7.8	0.90	8.5	0.78	5.6	0.72	1.5
Chlorine ..	0.65	—	0.90	—	0.51	—	0.44	—
Nitrogen ..	1.92	—	2.03	—	2.04	—	2.52	—

It is perhaps surprising to find from the figures such a small difference in chemical composition between the plots untouched (series C), those grazed only in September (series A), and those grazed in October and December (series D.) For though the D series consisted of newer and fresher growth than the other two series, it is only slightly richer in protein and actually contains as high or a slightly higher proportion of fibre. This is undoubtedly to be accounted for by the fact that the sample contained a fair proportion of stem and weeds left untouched by the December grazing. It will be noted that the plants grazed monthly are decidedly richer in protein, but that the percentage of fibre was here actually at its highest, while the lime and chlorine were lower than on any other plot, the series grazed only in September being richest in phosphoric acid and lime.

From the point of view of production of nutrients it will be observed that the ungrazed series and those only grazed in September are the highest yielding.

Although the totally ungrazed series (C) gave a higher yield of dry matter than that grazed only in September (A) (see Table III), it is interesting to note that the latter has given the most satisfactory result as to nutrients. The protein yield is practically as high on the September grazed plots as on the ungrazed plots, while the fibre is considerably lower on the former series which have also been productive of as much or more phosphoric acid, lime and silica-free ash. It has, however, already been noted that the September grazed plots contained considerably more Italian rye-grass on the crucial spring date than did the ungrazed plots (see Table III). The yield of the various nutrients from the monthly grazed series as a consequence of the necessarily low yield of dry matter is relatively slight.

(b) *The separations.*

Seeing that sheep prefer the leaf of Italian rye-grass to either the stem of that species or to bent, daisies and burned foliage, the results of the chemical analysis of these separations are likely to throw considerably more light on the grazing value of the several plots than merely the results of the analysis of the bulk samples. The chemical data of the separations are set out in Table XVI, which gives their percentage composition, and Table XVII, giving the yield of the more important nutrients.

In order further to facilitate comparison the total yields of dry matter of the separations together with the yields of fibre, crude protein and silica-free ash in each case are shown graphically for the four series of plots in Figure 4.

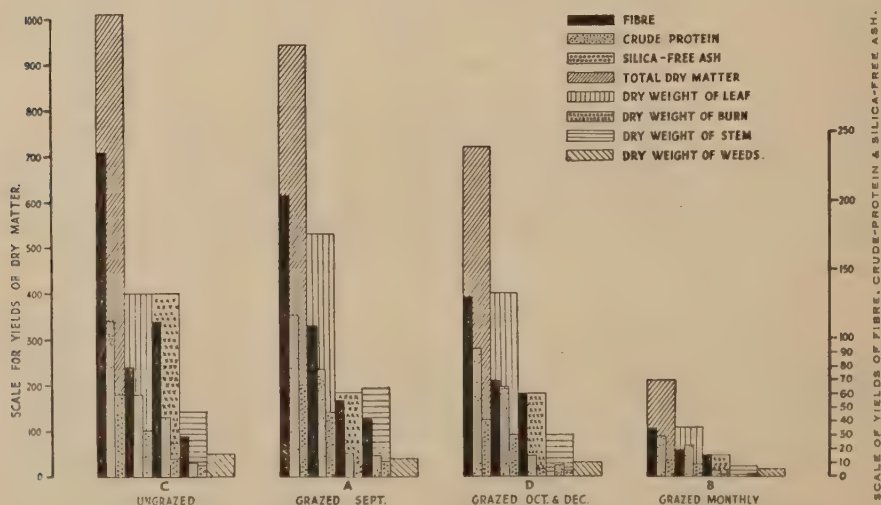


Fig. 4. To show graphically the total yield of dry matter in lb. per acre, together with the various separations from each of the series of plots at the crucial spring date (March 30th). The calculated yields of fibre, crude protein and silica-free ash are also shown.

TABLE XVI. To show the chemical composition of the stem and leaf of Italian rye-grass, weeds and burned material respectively for the four series of plots when sampled at the commencement of the crucial grazing period (March 30th).

Constituents.	Series C.				Series A.			Series D.			Series B.		
	Ungrazed from corn harvest.				Grazed only in September.			Grazed in October and December.			Grazed monthly.		
	Stem *	Leaf *	Weeds †	Burn	Stem	Leaf	Weeds	Burn	Stem	Leaf	Weeds	Burn	Stem
Ether extract ..	1.05	4.50	2.10	2.65	1.46	4.33	—	2.88	—	4.09	—	1.58	—
Crude protein ..	7.18	15.34	—	10.62	7.57	14.69	17.37	10.13	8.37	16.22	15.06	8.43	—
True protein ..	—	12.09	—	9.56	6.71	11.28	14.00	9.06	7.81	13.72	—	8.31	—
Fibre ..	20.38	19.99	27.40	28.38	21.68	20.64	—	29.95	—	17.36	—	33.50	—
Ash ..	6.64	9.43	8.00	8.80	6.84	10.21	9.87	8.13	5.89	9.06	8.03	7.48	—
Soluble carbohydrates ..	64.75	50.74	—	49.55	62.45	50.12	—	48.91	—	46.73	—	49.01	—
Silica (SiO ₂) ..	0.94	1.14	1.53	5.30	1.02	1.41	2.00	4.33	1.03	1.55	2.03	4.68	—
Silica-free ash ..	5.70	8.29	6.47	3.50	5.82	8.80	7.87	3.80	4.86	7.51	6.00	2.80	—
Phosphoric acid (P ₂ O ₅) ..	0.89	0.80	0.90	0.50	0.67	0.78	0.85	0.52	0.66	0.76	0.77	0.41	—
Lime (CaO) ..	0.44	1.02	1.02	0.79	0.54	1.09	1.09	0.92	0.42	1.02	—	0.73	—
Chlorine (Cl) ..	0.91	1.12	—	0.16	0.91	1.27	—	0.42	—	0.96	—	1.15	—
Nitrogen (N) ..	1.15	2.45	—	1.70	1.21	2.35	2.78	1.62	1.34	2.59	2.41	1.35	—

* Stem and leaf are of Italian rye-grass only.

† "Weeds" consist chiefly of bent (*Agrostis vulgaris*) and daisies.

TABLE XVII. To show the calculated yield of the chief nutrients in lb. per acre for stem and leaf of Italian rye-grass, weeds and burned material respectively for the four series of plots when sampled at the commencement of the crucial grazing period (March 30th).

Constituents.	Series C.				Series A.				Series D.				Series B.			
	Ungrazed from corn harvest.				Grazed only in September.				Grazed in October and December.				Grazed monthly.			
	Stem *	Leaf *	Weeds †	Burn	Stem	Leaf	Weeds	Burn	Stem	Leaf	Weeds	Burn	Stem	Leaf	Weeds	Burn
Crude protein..	10.40	61.60	—	42.56	14.50	77.80	6.80	18.40	7.70	65.00	4.5	15.20	—	22.5	2.60	3.80
True protein ..	—	48.50	—	38.30	12.90	59.70	5.50	16.50	7.20	55.00	—	15.00	—	17.4	2.30	3.20
Fibre ..	29.50	80.20	14.10	113.70	41.60	109.20	—	54.50	—	69.40	—	60.30	—	18.3	—	15.50
Silica-free ash ..	8.30	33.30	3.30	14.00	11.20	46.60	3.10	6.90	4.50	30.00	1.8	5.00	—	8.2	0.93	1.30
Phosphoric acid(P ₂ O ₅) ..	1.30	3.20	0.46	2.00	1.30	4.10	0.33	0.94	0.60	3.04	2.3	0.74	—	0.18	0.13	0.18
Lime (CaO) ..	0.64	4.07	0.53	3.20	1.04	5.75	0.42	1.67	0.40	4.07	—	1.30	—	1.1	0.18	0.30

* Stem and leaf are of Italian rye-grass only.

† "Weeds" consist chiefly of bent (*Agrostis vulgaris*) and daisies.

Taking the results as a whole it will be seen that in all cases the leaf is nearly twice as rich in protein as is the stem (see Table XVI). Further, on comparing the plots it is to be observed that the figures for leaf show a greater difference than those for the bulk samples (see Tables XV and XVII). The leaves from the plots grazed in October and December are, for example, appreciably richer in crude and true protein than are the leaves from the plots left ungrazed and from those only grazed in September, while the leaves from the plots grazed monthly are particularly rich in both crude and true protein. These are highly significant facts when taken in conjunction with the preference shown by sheep for leaf and with the evidence from the sheep register previously discussed.

The silica-free ash is also appreciably higher in the leaf than in the stem, though the difference between the plots in this constituent is not considerable.

At this date (March 30th) the stem and leaf show but little difference in phosphoric acid* compared with the difference found between them in lime, the leaf being twice as rich as the stem in the latter constituent (see Table XVI). In the stem there is an excess of phosphoric acid over lime, but in the leaf the lime is higher than phosphoric acid, with the important result that the ratio of phosphoric acid to lime is high in the stem but low in the leaf.

Previous work with cocksfoot and other grasses cut at intervals during the normal growing season has generally shown the stem to be slightly richer in phosphoric acid than the leaf; and has also shown the leaf to be decidedly richer in lime.*

The analysis of the burn shows it to be poor in protein, silica-free ash and mineral constituents. When this fact is considered in conjunction with yield, the effect of the burned product, largely neglected by sheep, on the composition of the bulk sample will be readily appreciated.

The particulars given in Figure 4 show that not only did the plots grazed in September give the highest yield of leaf at the crucial date, but that leaf gave the highest yield of protein, and that although series D was grazed in December it yielded practically as much leaf as series C (ungrazed), and rather more protein from the leaf.

Though the leaf of the series monthly grazed contributes little to the bulk (see Table XVII), and consequently supplies less protein than the leaf of any other plot, yet in proportion to its weight it supplies more than any other.

(6) *Cuts made at the termination of the crucial spring grazing period (April 13th). Series A, C and D.*

The analyses made on the bulk samples after the termination of the grazing period are given in Table XVIII. Data are not included for the monthly grazed plots (series B) because they had been so closely grazed that it was impossible to harvest a sample.

If the figures in this table are compared with those representing the produce before grazing commenced (see Table XV) it will be seen that in the case of each plot the crude and true protein is higher before grazing than afterwards. In the case of fibre the position is reversed, the highest percentage of fibre being in the samples taken after grazing. There is no very great difference in silica-free ash and mineral constituents before and after grazing. The chemical evidence thus supports the botanical and sheep evidence, and shows that the sheep gave most attention to the relatively young and succulent herbage available on the plots.

* See Fagan and Jones (3); Fagan and Evans (2).

TABLE XVIII. *To show the chemical composition of the bulk samples from three series of plots immediately after the crucial grazing period (April 13th). Series A, C and D.*

Constituents.	Series C.			Series A.		Series D.	
	Ungrazed from corn harvest.			Grazed in September only.		Grazed in Oct. and Dec.	
Ether extract	2.90			3.50		2.87	
Crude protein	11.97			10.56		12.09	
True protein	10.12			10.06		10.78	
Fibre	26.44			25.67		26.97	
Ash	8.79			8.68		8.64	
Soluble carbohydrates	49.90			51.59		49.43	
Silica	3.50			3.04		3.34	
Silica-free ash	5.29			5.64		5.30	
Phosphoric acid (P_2O_5)	0.63			0.68		0.62	
Lime (CaO)	0.86			0.95		0.83	
Chlorine (Cl.)	0.69			0.84		0.60	
Nitrogen (N)	1.91			1.69		1.93	

Analyses made on the leaves of Italian rye-grass after the grazing period, compared with those made previously, tend to show that on the plots with the more mature herbage (series C ungrazed and series A grazed only in September), the sheep undoubtedly selected the relatively younger and more succulent leaves. The statement hereunder as to crude and true protein and fibre makes the position clear:—

Percentage of crude and true protein and fibre in the leaf of Italian rye-grass before and after the crucial grazing period.

		Series C ungrazed until March.		Series A grazed in September.	
		March 30th.	April 13th.	March 30th.	April 13th.
Crude protein		15.34	14.50	14.69	14.69
True protein		12.09	10.87	11.28	9.30
Fibre		19.99	24.72	20.64	24.33

(7) *Analyses of the green and yellow portions of the leaves.*

Owing to the observed difference in palatability between the abnormal yellow and normal green portions of the leaves of Italian rye-grass previously referred to (see p. 11), it was thought desirable to subject each to chemical analysis. The results are given in Table XIX.

The results show that the normal green leaf contains appreciably more crude protein than the abnormal yellow—the difference in true protein is, however, but slight. The yellow portion is lower than the green in ash and silica, but the amount of phosphoric acid is slightly higher in the yellow portion. The most striking difference is, however, in the lime content, the yellow portion on the three plots containing approximately twice as much as the green.

TABLE XIX. *To show the chemical composition of the normal green and abnormal yellow portions of the leaves of Italian rye-grass for three series of plots at the crucial date (March 30th). Series A, C and D.*

Constituents.	Series C.		Series A.		Series D.	
	Green.	Yellow.	Green.	Yellow.	Green.	Yellow.
Crude protein.. ..	15.50	11.81	15.25	11.62	16.00	13.50
True protein	11.81	10.36	12.00	11.43	12.94	—
Ash	10.97	8.65	11.18	8.70	—	—
Silica	2.14	1.05	2.50	0.60	—	—
Silica-free ash	8.83	7.60	8.68	8.10	—	—
Phosphoric acid	0.83	0.89	0.82	0.85	—	—
Lime	0.81	1.51	0.82	1.64	0.85	1.83
Nitrogen	2.48	1.99	2.44	1.86	2.56	2.16

V. THE CRUCIAL GRAZING PERIOD IN RELATION TO PRACTICE : SUMMARY OF THE EVIDENCE.

In the main the evidence of the sheep themselves and of the chemical and botanical analyses are in striking agreement with reference to the crucial grazing period. From the standpoint of practice much depends upon what use is to be made of the herbage during the period in question. If bulk is required for, say, store cattle, which do not show much selection in their grazing, there might possibly be something to be said for leaving the rye-grass ungrazed from corn harvest ; but it is probable that for all classes of stock, it is preferable to have grazed down the autumn growth late in September.

It is a striking fact that the plots so treated have produced the greatest amount of rye-grass leaf, and of protein from leaf, with much less burned material than the ungrazed plots, and practically no more burned material than the plots grazed in October and December. The useful herbage was most plentiful on plots so treated, and over a longer grazing period than that adopted, it is undoubtedly these plots which would have provided the greatest amount of reasonably succulent keep for sheep.

The early preference of the sheep themselves has, however, to be seriously reckoned with, and it is evident that plots grazed in October and December give not only much more green herbage than those grazed monthly, but also approximate more closely to them in attractiveness than to plots longer rested. It is to be remembered that these plots showed as high a proportion of rye-grass leaf as any, and that the leaf was richer in protein than either of the rested series, and also showed altogether less yellowing.

Thus when providing for ewes giving milk to their lambs, it might be better to sacrifice a certain amount of bulk, and graze once again after the autumn to encourage more succulent growth at the crucial period.

The chemical evidence supports the yield and botanical evidence in showing that over-resting of the rye-grass during the autumn and winter, results in a considerable loss of excellent material in so far as the whole period corn harvest to mid-April is concerned.

For this reason, and since " keep " is very scarce and urgently needed for " grass " sheep all the time from November to the end of April, it is probably

more economic to graze the greater proportion of such Italian rye-grass as is available, on a plan approaching that adopted on series D (grazed in October and December) and series B (grazed monthly) than to leave it totally ungrazed or to graze it only in the late autumn.

VI. GENERAL SUMMARY.

The chief results of the trial under review may be summarised as follows :—

1. Italian rye-grass during the period corn harvest to the end of March gave a larger aggregate yield when cut monthly than when cut once, twice or three times. This result is in the opposite direction to that previously obtained with perennial grasses cut during the period March to September. The behaviour of Italian rye-grass is to be explained partly by the fact that it recovers very quickly after grazing or cutting—far more quickly than the perennial grasses; and partly because growth made during the autumn and early winter, if not cut, will have largely rotted by March.

2. Italian rye-grass makes appreciable growth all through the winter: on each occasion even between December and March after but one month's rest, over 200 lb. of dry matter per acre or not less than 6 per cent. of the total yield was produced—and that herbage which was readily taken by sheep.

3. At the crucial spring date (March 30th) the largest yield of dry matter of green Italian rye-grass was produced by the plot grazed in September. The plot left ungrazed from corn harvest gave the highest aggregate yield of rye-grass (green and burned), bent and daisies, and the plot grazed in October and December gave a far higher yield of green rye-grass than that grazed monthly.

4. The plot left entirely ungrazed contained on March 30th the highest proportion of burned material as well as a high proportion of "yellowed" leaves of rye-grass. There was as high a proportion of burned material on the plots grazed monthly, and in October and December, as on that grazed only in September, but not nearly as much "yellowing" of the rye-grass leaves, yellowing being negligible on the plots grazed monthly.

5. The plots grazed monthly contained on March 30th the highest proportion of bent and daisies. This is to be accounted for partly by the fact that these had been largely neglected at each previous grazing; and further, because the heavy grazing of the rye-grass had begun to react to some extent on the vigour of the plants. The presence of bent in a higher proportion than on the other plots largely explains the relatively high percentage of burn, as it is a grass that burns very badly and was left untouched.

6. The plots grazed monthly, and those grazed in October and December, gave on March 30th a higher proportion of rye-grass leaf to stem than those grazed only in September or left ungrazed: the cuts made on September 21st, however, had a higher stem content than cuts made subsequently.

7. Evidence given by the sheep themselves (sheep register data), and from sampling before and after the crucial grazing period, show conclusively that sheep prefer the green leaves of Italian rye-grass to either the stem or burned portions of the leaf of that species, or to bent and daisies. Sheep neglect other products as long as green rye-grass leaf is available, but since a mass of burned material tends to render green leafage somewhat inaccessible, they will take burned material incidentally to the closer grazing of that green leafage.

8. Even after a nine days' grazing period, sheep showed a preference for the plots grazed monthly—although eaten down to such an extent that it was impossible to harvest a sample—to the plots previously ungrazed, although containing a considerable amount of green rye-grass leaves amid a mass of burned and mature material.

9. The sheep showed an altogether greater preference during the crucial period for the plots grazed in September to those left ungrazed, and after the first three days, when they had grazed the "monthly" and "October and December" plots very bare, they transferred their attention to the "September" plots.

10. Sheep having access to a number of plots of Italian rye-grass on and after March 30th, during a relatively restricted grazing period, take an amount of keep from the several plots in inverse proportion to the total amount available.

The greatest amount of material during fourteen days' grazing was taken from the plots previously grazed in October and December, and those grazed in September.

11. Since sheep have been shown to have such a decided preference for leaf, chemical analyses of the "bulk samples" are not as instructive as those of the separations (that is, stem, leaf, burn and weeds).

12. The systems of cutting have allowed of comparisons being made between the chemical composition of the herbage under long and short periods of growth, and under favourable and unfavourable conditions. Fibre tends to be relatively high and protein relatively low when growth has been rapid and the herbage is given time to mature, for example, growth August to September. When growth is slow, stem is only very slightly developed, and since root leaves continue to elongate but slowly, the herbage does not reach maturity; thus protein tends to be high and fibre low, and deterioration is not rapid.

13. The calculated total nutrients removed from the plots show that these are greater under a system of monthly cuts, than under a more lenient system of cutting.

14. At the crucial spring date, the total yield of nutrients was higher from the plots previously grazed in September than from those left ungrazed, for though the latter provided more dry matter, the former contained the most rye-grass.

15. Weeds (=chiefly bent and daisies) are poorer in protein and higher in fibre than Italian rye-grass, but a higher lime content in November and January shows that they can be fairly rich in mineral constituents.

16. Burned herbage is poor in protein, silica-free ash and mineral constituents, and relatively rich in fibre. "Yellowed" leafage is poorer in true protein than normal green leaf, but there is not much difference in crude protein, the yellowed portion is, however, nearly twice as rich in lime as the normal green.

17. Leaf (the blade only) of Italian rye-grass has shown itself to be nearly twice as rich in protein as the stem (in most cases chiefly the sheath of the leaf.) Silica-free ash and lime are also appreciably higher in leaf than in stem. In phosphoric acid there is little difference between stem and leaf, but the ratio phosphoric acid to lime tends to be lower in leaf than in stem. This very decided difference between "leaf" and "stem," confirming as it does previous

work, demands special emphasis. The sheep by their selective grazing thus take a food very appreciably richer in protein and silica-free ash than would be indicated by analyses made on a "bulk sample," while the ratio of the constituents to each other is also different. Thus when considering herbage as a ration for sheep, it must be remembered that it is "leaf" which gives a fundamental bias to that ration.

18. The "leaf" shows the condition of the several plots far better than the bulk sample. Thus on March 30th, the "leaf" on the plots grazed monthly and on those grazed in October and December, was appreciably richer in crude and true protein than the leaf on the plots left ungrazed and on those only grazed in September.

19. The more immature the "stem", the richer it is in protein and the poorer in fibre.

20. Analyses made after the crucial grazing period show a higher percentage of fibre and a lower percentage of protein than those made previously; this further indicates the selective grazing of sheep, and that they tend to take relatively young and immature herbage.

21. The practical conclusions to be drawn from the experiment as a whole have been stated in Section V., and briefly are as follows:—That in so far as maximum nutrients are concerned, which synchronise with maximum production of Italian rye-grass leaf, the highest yield will be obtained at the crucial spring date by grazing off the autumnal growth and then leaving till required. This is, however, a wasteful procedure, and in view of the fact that grazing is urgently needed during the whole period November to March, it is probably more economic to graze to a certain extent during the winter also, and this further provides a more attractive herbage for the sheep in March.

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THE SHEEP AS A GRAZING ANIMAL AND AS AN INSTRUMENT FOR ESTIMATING THE PRODUCTIVITY OF PASTURES.

by

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INTRODUCTION.

The influence of the biotic factor on the genesis of types of grassland has been abundantly shown by Pickworth Farrow (3), Tansley and Adamson (8), and others, while in New Zealand Cockayne (2) has demonstrated the effect of this factor on stable tussock grasslands, and in America, Sampson (5) has discussed the matter in relation to range and pasture management, and Levy (4) in New Zealand has insisted upon the necessity of supplementing sheep grazing with cattle in connection with the re-grassing of deteriorating scrub lands. The influence of the grazing animal on ordinary types of farm grasslands has never been critically studied in this country, though in a general way it has been commented upon by numerous writers.

Trials are now in progress at the Station with a view to estimating with precision the effect of grazing with sheep upon a number of plots representing different grasses and clovers.* These trials have tended to concentrate attention upon the behaviour of the sheep themselves, and it was therefore thought desirable to try to collect accurate information bearing upon the sheep as well as upon the pasture. It was thought that with a better knowledge of sheep regarded as grazing machines it might be possible to use them as instruments for gauging the productivity of pastures in a manner different from that of relying on their live weight increases.

So intimate is the connection between the grassland complex and all its reactions and the grazing animal complex and all its reactions that it appears obvious that it is not possible to understand the one complex without also understanding the other.

The evidence brought forward in this article is of a preliminary nature, and is intended chiefly to indicate the character of the technique which is being developed at the Station; the present aim being to invite criticism and to suggest lines of enquiry rather than to propound new facts.

I. YIELD PER ACRE AND AMOUNT ACTUALLY EATEN BY SHEEP.

Cockayne (1) writing of the production and earning power of New Zealand grasslands, gives as an average figure the consumption of 24 lb. of green grass per sheep per day (24 hours), or roughly 4 tons of green grass per annum. Thus land capable of carrying two sheep per acre would yield 8 tons of green grass per annum. These figures are in themselves interesting and naturally invite

* This trial (E. 37 I.) is now in its fourth harvest year and will be reported upon in detail in due course.

enquiry as to the amount actually eaten by sheep on different types of grassland and at different dates, and as to the yields of pasturage from very different types of grassland.

Material and methods.

With the object of ascertaining the amount of fodder produced per acre and the amount consumed by sheep per head per day a piece of ground was selected at the Station, which was fairly uniform and which had been sown with a mixture* of grasses and clover in the spring of 1924. This had been grazed by sheep at intervals up to May 14th, 1925, when a lawn mower was run over it in order to cut off what little growth remained as close to the ground as possible.

The area was then hurdled off into folds arranged as follows:—A strip 28 yards broad and 65 yards long was selected. This was divided laterally into alternate folds of 5 yards and 10 yards respectively. Thus the larger areas were 10 yards by 28 yards (=approximately $\frac{1}{17}$ acre)—these constituted the folds in which in each case two sheep were penned. The smaller areas were 5 yards by 28 yards (=approximately $\frac{1}{34}$ acre)—these constituted the control plots, from which the produce was cut after each grazing period. The weight from the control on each side of a grazing pen was taken to represent the weight of produce on that pen before grazing began.

On May 28th, 1925, two sheep that had been weighed were placed in each of the four grazing plots and allowed to remain there for five complete days. On June 3rd each of the grazing plots and the control plots was again cut as close to the ground as possible, first by means of a horse mower and then with a lawn mower, and the produce of each area was weighed separately. The produce was collected and weighed as quickly as possible so as to obviate loss of weight due to drying. A representative sample of each plot (2 lb. in weight) was also taken at this stage. These samples were air-dried to a constant weight in order to ascertain the amount of dry matter in each plot.

The hurdles were then removed and all the plots treated alike until June 2nd, 1926, when a similar experiment was repeated on the same ground. In order to avoid any residual effect from the previous year all the plots were moved along to the extent of two-thirds of the width of the control plot, namely, 10 feet. On June 26th two sheep were again placed in each plot where they remained for six complete days. As soon as the sheep were turned out both the grazed plots and the control plots were cut, as in the previous year, and samples were taken. The samples taken in this case were separated into clovers, perennial rye-grass, other grasses and weeds, and each of these classes was separated into stem and leaf.

The plots were then allowed to grow without being grazed, and those which had been grazed resembled so closely those which had not been grazed that the experiment was carried out again without moving the hurdles, and on August 6th, 1926, two sheep that had been weighed were placed in each grazing plot. On August 17th these were turned out and the plots cut and sampled as before.

* The mixture was as follows in lb. per acre:—

Perennial rye-grass (indigenous)	7.5
Cocksfoot (do.)	5.0
Red Clover (Montgomery late)	10.8
lb. per acre	23.3

TABLE I. *Showing productivity per acre, consumption per head of sheep, sheep carrying capacity per acre, and other data in respect of the folding experiment.*

Reference.	Tabulation of Data (Yields per acre).	1925 May 14th— June 3rd.	1926 June 2nd— July 2nd.	1926 July 2nd— Aug. 17th.
1	Duration of period of growth <i>in days</i> ..	20	30	46
2	Yield of green herbage (as weighed) during the various growth periods— <i>in tons</i>	1.03	2.34	4.7
3	Yield of green herbage calculated from yield of dry matter during the various periods— <i>in tons</i>	1.20	1.86	3.13
4	Yield of dry herbage (dry matter) during the various periods— <i>in tons</i> <i>in lb.</i>	.277 620	.428 960	.720 1610
5	Growth per acre per day : green herbage calculated from dry matter <i>in lb.</i> ..	135	139	152
6	Growth per acre per day dry herbage (dry weight) <i>in lb.</i>	31	32	35
7	Duration of period of grazing <i>in days</i> ..	5	6	11
8	Consumption per sheep per day of green herbage as weighed <i>in lb.</i>	9.8	16.7	24.2
9	Consumption per sheep per day of green herbage calculated from dry matter <i>in lb.</i>	11.3	11.3	14.8
10	Consumption per sheep per day of dry herbage (dry matter) <i>in lb.</i>	2.6	2.6	3.4
11	Carrying capacity of sheep per acre calculated on dry weight figures ..	11.9	12.3	10.3
12	Average weight per head of sheep <i>in lb.</i> ..	122	130	137
13	Weather during period of growth ..	fairly moist.	fairly moist.	wet.
14	Weather during period of grazing ..	fairly dry.	very dry.	wet.
15	Weather on day of cutting	very rapid drying.	very dry.	damp.

- NOTES. 2. The weighing was rapidly performed after cutting, but since the conditions were very dry at the time of cutting for the 20 and 30 day periods of growth, these figures are not directly comparable to those for the 46 day period.
3. Based on proportion of dry matter of green herbage at 23 per cent., this figure being the average for red clover and grasses obtained from numerous trials at the Station.
5. Calculated on the same basis as Note 3 above.
8. Subject to the same reservation as Note 2 above.
9. Calculated on the same basis as Note 3 above.
12. There was a slight variation in the average weight of the sheep, but this was due more to condition than to actual size.

Discussion.

The various results from the experiment are set out in detail in Table I. The figures are of considerable interest from many points of view. Taken in conjunction with the other experiments discussed they throw important light on the grazing yield of temporary grass. If the green grass weights calculated from dry matter are used we obtain the following result :—

- (1) Period May 14th to August 17th (=95 days) on
average of yield per day from Table I. =6.03 tons per acre.

- (2) Period August 18th to May 13th (=270 days) on
 average of yield from monthly cuts from plots dealt
 with in the previous article =6.63 tons per acre.
 Total yield of green grass per acre per annum, say .. =12.66 tons per acre.

This yield represents a high production of nutrients having regard to the chemical data previously discussed and to the results reported by Woodman and his co-workers from Cambridge (9). The figure is perhaps not as high as Cockayne's estimates (he appears to look for 18 tons of green grass per annum from a temporary ley) might have led one to expect, but it must be remembered that the figure here recorded has been definitely based on green grass only containing water of constitution and with no extraneous moisture attached.

It will be seen from the table that Cockayne's estimated consumption per sheep per diem, namely, 24 lb., must be regarded as high. For sheep of an average weight of about 130 lb. although confined and placed on abundant herbage have only once consumed this amount, and then only when wet herbage obviously carrying extraneous moisture has been considered. The consumption of green grass as such has varied from about 11 lb. per diem to nearly 15 lb., and of dry matter from about 2½ lb. to 3½ lb.

The figures appear on the face of it to show that within limits the sheep tend to eat more in proportion as the production of herbage per day is high. Thus with a dry weight production of 35 lb. per day the sheep have consumed 3.4 lb., while with a dry weight production of 31—32 lb. per day they have eaten 2.6 lb. Since in each case, however, the herbage was abundant the difference above noted could possibly be explained by supposing that sheep actually eat more true grass (more dry weight) when the herbage is moist than when it is decidedly dry.*

The weather data would seem to lend support to this assumption as would the proportional takings per sheep per day when looked at from the point of view of dry weight, dry green grass, and moist green grass (cf. figures of references 8, 9, and 10, for each grazing period in the table).

It is to be noted that although the weather was favourable to growth and the yield high during July—August, the carrying capacity was yet lower than in June, due of course to the sheep eating more during the former period. It is possible, if not probable, that this greater consumption was due not so much to the greater bulk offering or to the moist condition of the herbage as to a difference in chemical composition as between one period and the other. In this connection it is noteworthy that in the August grazing, clover stem was very predominant in the herbage, while in the June grazing, clover leaf was most predominant. Thus in August the sheep consumed the equivalent of 525 lb. of clover stem per acre, while they consumed but 124 lb. of clover stem in June (see Table II., p. 46, and discussion regarding stem and leaf in subsequent section).†

* The sheep in all the pens were provided with water for drinking.

† Mr. Fagan has kindly provided the following figures which show that the stem of red clover (Montgomery late) is less rich in crude protein than the leaf. The difference between stem and leaf is not, however, so great as in the case of the grasses.

Pasture cuts on Montgomery red clover made on—	Percentage of crude protein in—	
	Stem.	Leaf.
April 2nd, 1923.	20.18	29.47
May 2nd, 1923.	21.37	29.67
June 28th, 1923.	—	29.33
July 26th, 1923.	21.25	28.10
August 24th, 1923.	21.47	30.09
September 26th, 1923.	22.54	26.53

The figures as a whole show that there is much more variation in the consumption per day by the sheep when moist herbage is considered than when dry matter is taken into account. The fact that there is none the less a very decided variation in dry matter consumption even when sheep are penned on an abundant herbage is, however, the most significant point brought out by the little experiment. This tends to show that the method of enquiry here outlined, if followed up on pastures of various types, at different seasons of the year and for a number of years, would be likely to throw a flood of light on the inter-relations of the pasture complex and the grazing animal complex.

II. SELECTIVE GRAZING: EFFECT OF GRAZING ON THE PASTURE.

The preference shown by sheep for the leaf blade as opposed to the leaf sheath and stem proper has been alluded to in the previous article. Further data were obtained in connection with the trial dealt with in the last section. The evidence from the separations made on the produce before and after the grazing periods are set out in Tables II, III and IV. The composition of the actual produce grazed by the sheep has been deduced by subtracting the dry weight yields of each grazed plot from the sum of the corresponding dry weight yields of the two adjoining control plots, for as before explained, each control plot was half the area of the grazed plot.

TABLE II. *Showing yields per acre in lb. dry weight of the various constituents present in the pasture before grazing and the amount of each grazed. July 2nd and August 17th, 1926.*

	Clovers.		Perennial rye-grass.		Other grasses.		Weeds.
	Stem.	Leaf.	Stem.	Leaf.	Stem.	Leaf.	
<i>July 2nd, 1926.</i>							
Yield before grazing ..	176	249	177	67	112	170	12
Actual grazing ..	124	186	43	45	33+	94	0
Yield after grazing ..	52	63	134	22	79	76	12
<i>August 17th, 1926.</i>							
Yield before grazing ..	620	265	33	205	72	417	4
Actual grazing ..	525	249	11	139	44+	317	1
Yield after grazing ..	95	16	22	66	28	100	3

TABLE III. *Showing variation in yield of the several species due to grazing. July 2nd and August 17th, 1926.*

	Clovers.	Perennial rye-grass.	Other grasses.	Weeds.
<i>June 26th—July 2nd.</i>				
Before grazing	44.0 per cent.	25.3 per cent.	29.2 per cent.	1.3 per cent.
Actual grazing	59.1 ..	16.6 ..	24.4 ..	0.0 ..
After grazing	26.1 ..	35.3 ..	34.8 ..	4.0 ..
<i>August 6th—17th.</i>				
Before grazing	55.0 ..	14.6 ..	30.3 ..	0.3 ..
Actual grazing	60.1 ..	11.6 ..	28.1 ..	0.1 ..
After grazing	33.9 ..	26.6 ..	38.7 ..	0.8 ..

TABLE IV. *Showing variation in proportion of leaf to stem (as per cent. leaf in total of stem and leaf) due to grazing. July 2nd and August 17th, 1926.*

		Clovers.	Perennial rye-grass.	Other grasses.
<i>June 26th—July 2nd.</i>				
Before grazing		58.4 per cent.	27.3 per cent.	60.0 per cent.
Actual grazing		60.0 "	51.2 "	73.8 "
After grazing		54.5 "	14.1 "	49.0 "
<i>August 6th—17th.</i>				
Before grazing		30.2 "	86.0 "	85.3 "
Actual grazing		32.2 "	92.5 "	87.5 "
After grazing		14.5 "	75.0 "	78.5 "

It is interesting to note that the grasses (perennial rye-grass and cocksfoot chiefly) and the clovers (red clover) contributed fairly equally to the grazing, but whereas the growth made during June consisted predominantly of rye-grass stem and clover leaf, that made during July and early August consisted predominantly of clover stem and grass leaf. This is in accord with previous trials and is due of course to the later flowering period of the clover—the grass and clover being admirably complementary to each other from the point of view of grazing, each producing maximum bulk and maximum leaf at different periods.

It will be noted that at each grazing period the sheep showed a very decided preference for the red clover rather than for the grasses, and that on each occasion they left the weeds practically untouched. At each grazing, cocksfoot was preferred to rye-grass and in a proportion decidedly in advance of the relative position taken by the two grasses before the grazing period began. These figures lend support to the view generally held that perennial rye-grass is not amongst the most sought after grasses at the height of the summer, and that cocksfoot when grazed on a proper intermittent basis and not allowed to reach an advanced stage of maturity is highly palatable.

The data show that in the case of red clover the sheep grazed the stem as well as the leaf* in practically the same proportions as they occurred on the pasture before grazing began.

If the percentage of leaf of the clover before and after grazing is, however, compared, it will be noted that there was a certain preference shown for the leaf, and particularly at the August period, when stem was not only abundant but was standing at a high proportion compared to leaf.

In the case of the grasses the percentages of leaf before and after grazing given in Table IV show in each instance a lower percentage after grazing and thus a preference for leaf. This was markedly so during the late June—early July grazing period when stem was most prominent, for the sheep actually took a greater weight of leaf than of stem, although in the herbage offering there was practically three times as much stem as leaf. The figures in Table II. indicate that the sheep preferred the stem of cocksfoot to that of rye-grass; thus at the second grazing period they eat only a third of the offering stem of rye-grass, while they eat more than half of that offering of cocksfoot. This "stem" was,

* The petioles of the leaves were included with the stem and not with the leaf separation.

of course, almost wholly "leaf sheath" and was itself succulent, representing as it did only a little more than a month's growth.

The figures as a whole are in marked confirmation of those given in the previous article, and are of the greater interest as showing that even when growth is rapid and at the height of the season and when grazing is begun before the herbage has attained to an advanced stage of maturity, the sheep still show an unmistakable preference for the leaf blades of the grasses.

Further evidence was obtained from an experiment (E. 72 IV) laid down on May 6th, 1926. A number of plots were sown with mixtures containing 4-16 lb. Italian rye-grass with smaller quantities of seven other species. The plots had been cut in the late autumn (Oct. 8th) of 1926 and then allowed to grow undisturbed. All the plots were sampled on January 5th, 1927, and immediately afterwards 50 sheep were turned on the experimental area of $\frac{1}{3}$ acre for 20 hours. After this grazing period the plots were again sampled—that is to say, they were so sampled on January 6th.

At this period the bulk of the herbage consisted of Italian rye-grass, so that it is unnecessary to discriminate between the species. The produce as a whole from each series of plots before and after grazing was separated into grass leaves, grass stem, weeds, stubble (left from the autumn cut) and burned material. Average figures for all the plots are given in Table V.

TABLE V. *To show the yield per acre (dry weight) and percentage contribution to the aggregate bulk of the various separations made on a series of plots immediately before and immediately after a period of 20 hours' grazing. The percentage of each ingredient actually grazed is also shown.*

Separations.	Before grazing. January 5th, 1927.		After grazing. January 6th, 1927.		Per- centage of each ingredient grazed.
	Weight.	Per cent.	Weight.	Per cent.	
Grass stem (chiefly Italian rye-grass sheath)	31	5.8	15	7.1	49
Grass leaves	220	41.9	45	22.7	79
Weeds	1	0.1	trace	0.1	0
Stubble	54	11.0	42	21.4	22
Burned leafage	204	41.2	102	48.7	50
Total weight per acre ..	510	—	204	—	—

The figures in the table may be taken as practically absolute since a 20 hour grazing period during January would not have permitted of any error creeping in as the result of slight contemporaneous growth.

It will be noted that taking "burn" and "stubble" together over half of the material available consisted of non-green and non-functioning tissue which tended to make the green grass leafage relatively inaccessible. It has, however, been the green leaves which have attracted the sheep most, as much as 79 per cent. of the leafage offering having been consumed. Stem and burn have been grazed about equally, while the stubble has also been taken to an appreciable extent.

This evidence is in further support of that given above and in the previous article, and tends to show that when "burn" is very abundant on a sward it is eaten to an appreciable extent—probably not as a matter of preference but because it is almost impossible for the sheep to take the green foliage without also removing a large proportion of the burned material.

That sheep in fact graze in a highly selective manner has been conclusively proved by the data presented. This fact needs particular emphasis at the present time when the importance of close grazing is being canvassed on all sides with reference to obtaining the maximum amount of nutritious keep from pastures.

It has been shown by work previously reported from the Station that continuous heavy grazing reacts adversely on the root development of the plant, and is therefore capable of doing infinite harm. This is especially true if heavy grazing is started too early in the spring and particularly if a dry summer follows. It is of course true that Leicestershire and Romney Marsh practice aims at keeping the swards closely grazed, but it is equally true that the most skilled graziers are careful not to begin intensive grazing until the growing season has definitely commenced and the "ground is well covered." Selective grazing tends to hamper the more palatable plants to a greater extent than the less palatable. This is a point which has been noted and insisted upon by Cockayne.* There are not many plants which although highly palatable can stand heavy grazing at critical periods of the year without suffering harm. It is probable that of plants largely contributing to our grasslands wild white clover attains most nearly to this ideal, while on the Montane tussock grasslands of New Zealand sheep's sorrel appears to be such a plant.† Selective grazing in May and June is undoubtedly a contributing factor to the grasses running rapidly to inflorescence, since the sheep prefer red clover to the grasses when this species is present. This relatively heavier grazing of the red clover at a period when maximum growth of this species has not fairly started also tends to react adversely on the persistency of the clover and incidentally to delay stem and flower production. In order to level up the effect of the animals and to maintain the grasses in a leafy condition the mowers should always be run over sheep pastures when the grasses are throwing up inflorescences.

The influence of heavy grazing early in the spring on bent (*Agrostis* spp.) has been discussed in a previous report.‡ In this connection it is of interest to note that although bent is often abundant on Leicestershire pastures it never dominates such pastures—they are not heavily grazed early in the spring. The evidence discussed in this and in the previous article will have served sufficiently to indicate the effect of selective clover and grass grazing on the spread of the weed flora.

Those who are obsessed with the importance of almost continuous heavy grazing are prone to cite the case of fields heavily manured near homesteads which continue amazingly productive despite the treatment. Doubtless they do—but how much more productive might they not be if grazed on a more scientific plan? Evidence at the Station tends to show that heavy dressings with

* See Cockayne, L. *loc. cit.*

† That palatability is relative and is largely a function of the character of the herbage offering is well shown by the fact that on the Montane Tussock pastures of New Zealand (very poor pastures) sheep's sorrel is largely sought by sheep and closely grazed.

‡ See Stapledon and Davies (7).

nitrogenous manures are not competent to counteract the influence of continuous cutting (and therefore of grazing) on the root development of the plants so treated.*

The upshot of the whole matter is that at present we know little or nothing as to the precise effect of the grazing animal on our pasture lands. We know enough, however, to appreciate that the grazing animal is undoubtedly the master factor affecting the quality and productivity of our grasslands, and we are in a position to opine that rational grazing should be rotational and intermittent in character, the plants being given certain periods during the growing season for the more or less unhampered development of leaf in order to maintain their roots in a healthy and vigorous condition. Equally, over-mature, drying and dead, or dying herbage and herbage run to inflorescence should not be allowed to stand, and if the grazing animal is incapable of removing it recourse should immediately be had to the mowing machine.

III. CONTINUOUS OBSERVATIONS ON SHEEP FOR A PERIOD OF TWENTY-FOUR HOURS.

Apart from the economic factors of time and place, the value of a pasture is usually governed by the amount of animal increment it will produce. Broadly speaking this increment is determined by the amount of nutrients which the animal acquires less the amount used in the digestive processes and in the maintenance of the body. This latter amount may be supposed to vary according to the energy which has to be spent in collecting and digesting the food.

The behaviour of the animal, that is to say, the amount of time spent in performing various functions on a particular pasture is therefore considered to be a matter of considerable importance, and consequently with a view to collecting some information on the subject the following observations were made.

Material and methods.

The behaviour of two sheep† of the Kerry Hill breed, which were penned on a fresh succulent pasture in connection with the trial discussed in Section I. of this report, was observed continuously for a period of twenty-four hours, and a record kept of the actual occupation of each, that is, time spent grazing, chewing the cud, lying down, standing and walking about. In order to distinguish the two sheep particularly during the night a broad black band was tied over the back of one of them. The observations during the night were made with the aid of an electric torch in such a way as to disturb the sheep as little as possible. The first period of observation consisted of the 24 hours beginning at 9-30 a.m. on June 23rd, 1925. The day was throughout hot and sunny and the sheep were constantly irritated by flies, while the night was calm and cool. The second period of observation extended from 10-20 a.m. August 9th, 1926, to 10-20 a.m. the following day. There was a marked contrast in the weather during the two periods: in 1926 the day was mostly dull, whilst during the night there was a thunderstorm accompanied by very heavy rain.

* See Stapledon and Beddows (6).

† The sheep in each case had been in the pens for a few days before the observations were made, and consequently had become fully accustomed to their surroundings when the records were taken.

The weather conditions obtaining during the periods of observation are indicated by the statement hereunder.*

	<i>Rainfall.</i> <i>inch.</i>	<i>Sunshine.</i> <i>hours.</i>	<i>Maximum</i> <i>temp.</i>	<i>Minimum</i> <i>temp.</i>
June 23rd, 1925..	0	11.5	62°F.	45°F.
August 9th, 1926	1.29	2.7	64°F.	56°F.

Discussion.

The data collected are set out in Table VI, and are presented as a percentage of the various periods under review.

TABLE VI. *Showing behaviour of sheep at different periods of the day. (Average of 2 ewes each). Figures as per cent. of hours available.*

Greenwich mean time.	Grazing.	Chewing the cud.	Lying down not chewing.	Standing not chewing.
<i>June 23rd, 1925—24 hours ..</i>	21.0	25.0	50.0	3.0
Day, 6 a.m.—6 p.m. ..	16.8	20.7	58.2	4.1
Early morning, 3 a.m.—6 a.m. & Evening, 6 p.m.—9 p.m. ..	34.1	35.8	28.6	1.5
Night, 9 p.m.—3 a.m. ..	17.9	23.9	57.0	1.2
<i>August 9th, 1926—24 hours. ..</i>	30.0	23.0	11.0	29.0
Day, 6 a.m.—6 p.m. ..	32.0	39.0	20.5	8.5
Early morning, 3 a.m.—6 p.m. & Evening, 6 p.m.—9 p.m. ..	41.5	13.8	13.0	31.8
Night, 9 p.m.—3 a.m. ..	15.6	7.0	12.9	64.5

Though the data recorded are for two sheep only in each case, they were confirmed in a general way by observations on the sheep in the adjoining pens throughout the periods under review. The data in the table serve to indicate that on this particular pasture the sheep under confinement spent approximately half their time in feeding—grazing and chewing the cud. Under favourable weather conditions practically the whole of the remaining time was spent in resting. On a scanty pasture and where the grazing would be more selective, it is highly probable that the animal would spend more time in acquiring a sufficient supply of food; while in the case of a more fibrous herbage it is probable that a greater proportion of the time would be spent in chewing the cud.

The time of the day or night devoted to feeding or resting depended largely on weather conditions. In general there was a tendency for resting during the hours of darkness, while feeding was indulged in most actively during the hours of daylight, the early morning and the late evening being preferred for grazing. When, however, the conditions during the day—excessive heat and irritation by flies—caused discomfort, there was a tendency for more of the night time to be utilised in chewing the cud. Owing to the limited space available inside the pens there was practically no time devoted to roaming about, and by far the greater portion of the resting time was spent in lying down when the weather

* These readings were taken at the Meteorological Station which is adjacent to the pasture and are for the period from 9 a.m. to 9 a.m.

was dry in the 1925 period. In the 1926 period, however, there was a thunderstorm at night accompanied by very heavy showers of rain, and it was noticed almost invariably that the sheep stopped grazing and, if lying down, stood up and remained standing during the heavy showers.

The figures here presented are as they stand only of academic interest. The method of procedure is, however, as such worthy of consideration, and if adopted on contrasting pastures of very different carrying capacity might be expected to reveal very significant facts relating both to the sheep complex and to the pasture complex.

It would be desirable on each pasture type to note the behaviour of sheep both when penned and when at large, although it might not be easy to keep sheep having a free run under accurate observation throughout the 24 hours.

It is more than probable that a combination of the methods here discussed—namely, by sampling and cutting to ascertain the yield of a pasture and the amount and kind of herbage actually eaten by the sheep, together with observations on the manner in which typical sheep dispose of their time—might give more reliable and more critical information as to the stock-carrying capacity of different pastures or of fields differently treated, than arriving at the live weight increase of sheep penned on different plots. The latter procedure in any event gives no information as to precisely how one treatment has been superior to another. The data would not, however, be complete unless it was also possible to record the distance sheep walked when confined to grazing of different types.

It is hoped to develop and extend this line of enquiry and arrangements are being made to add considerably to the scope of the work during the current growing season.

IV. SUMMARY.

1. The importance of the biotic factor in relation to grassland has been insisted upon.

2. A technique has been described for arriving at the yield per acre of grazable herbage from a pasture and for estimating the amount of that herbage actually eaten by sheep.

3. The yield per acre per annum of a temporary ley in which Italian ryegrass largely contributes to the winter keep may amount to 12.66 tons of green grass devoid of extraneous moisture.

4. The amount—even of herbage considered as dry matter eaten per day by sheep although penned on an abundant herbage—varies within considerable limits. It is not at present possible to say whether the variation is influenced most by the daily production of herbage, the degree of moisture of the herbage, or the botanical and chemical composition of that herbage. It was, however, noted as significant that more dry matter was consumed per day when the herbage consisted largely of clover stem than when it consisted largely of clover leaf.

5. The amount of herbage eaten per day varied from 9.8 lb. to 24.2 lb. when green grass plus extraneous moisture was taken as the unit and from 2.6 lb. to 3.4 lb. when dry matter was taken as the unit.

6. A technique has been described in this and the previous article for ascertaining the selective grazing of sheep on a quantitative basis. It has been

shown that sheep prefer the green blades of grass to either the green sheaths or the stem proper. They also prefer green leafage to either burned or drying material or to weeds. They prefer red clover to grasses, and although apparently showing a slight preference for the leaf of clover over the stem the difference is not nearly so pronounced as in the case of the grasses.

7. The effect of selective grazing on the persistency of both valuable grasses and clovers and on weeds has been discussed and practical conclusions have been drawn.

8. A technique has been described for ascertaining the amount of time sheep devote to performing various functions. Sheep penned on an abundant herbage spend about half their time feeding—grazing and chewing the cud, and about half their time resting.

9. In general, sheep rested during the hours of darkness and devoted the hours of daylight to feeding. The late evening and early morning were preferred for grazing. When conditions during the day were unfavourable more of the night time was spent chewing the cud.

10. During periods of heavy rain the sheep almost invariably stopped grazing, and if lying down stood up during the period of heavy rain.

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